

ORDOVICIAN TRILOBITES FROM CHEDAO, GANSU PROVINCE, NORTH-WEST CHINA

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ABSTRACT Two trilobite assemblages of middle Llandeilo to basal Caradoc and of Caradoc age are described from the type section of the Chedao Formation at Chedao, Huanxian County, Gansu Province, north-west China. They include twenty-nine taxa, of which five are new species: *Phorocephala quadrata*, *Peraspis obscura*, *Microparia (Quadrropyge) chedaoensis*, *Ischyrophyma? zhiqiangi*, and *Hammatocnemis obsoletus*. The composition of both assemblages approaches that of the Nileid Association and suggests that the Huanxian area formed part of the western slope of the North China carbonate platform. The presence of genera such as *Peraspis*, *Lyrropyge*, and *Cyphoniscus* indicates that some genera once thought to have a short stratigraphic range persisted much longer when appropriate environments were available.

THE Huanxian area from which the trilobites now described were obtained lies in eastern Gansu Province, eastern part of north-west China (text-fig. 1). The importance of Huanxian to Chinese Ordovician geology lies in its palaeogeographic position between the shallow-water shelf of the North China, or Sino-Korean, platform to the east and the deep basin of the Qilian Trough or Geosyncline to the west, terms used by Huang *et al.* (1977) and Jen *et al.* (1980). Lai *et al.* (1982) included the area in the western marginal belt of the North China carbonate platform. The macrofossil assemblages may be interpreted either as intermediate between those of basin and shelf or, as suggested by Lu (in Lu *et al.* 1976), of transitional type. Although the existence of Ordovician strata in the Huanxian area has been known for over twenty-five years (Lu 1959), only a few cephalopods (Chang 1962) and two trilobites (*Nileus huanxianensis* Zhou and *Pseudostygina lepida* Zhou, both in Zhou *et al.* 1982) have been described.

LOCALITIES AND STRATIGRAPHY

The well-preserved, but disarticulated, trilobites described here were collected from the measured section at Shixiezi, 8 km north-west of Chedao, Huanxian County (text-fig. 1); the base of the section is faulted against Cretaceous rocks, and the top is overlain by Recent loess deposits. The Ordovician rocks consist mainly of limestones of different colours (text-fig. 2), the purplish beds in the upper part of the section being termed Chedao Formation by Lin (in Lai *et al.*, 1982, p. 66). For present purposes, and on the basis of unpublished information from Fei Anqi and Liu Pingjun of the Changqing Bureau of Petroleum Prospecting, we use Chedao Formation for the whole succession, divided into thirteen numbered, informal beds, pending a formal revision of the stratigraphic terminology. Macrofossils were obtained only from Beds 4 and 12, and no conodonts were found.

Macrofossils from Bed 4

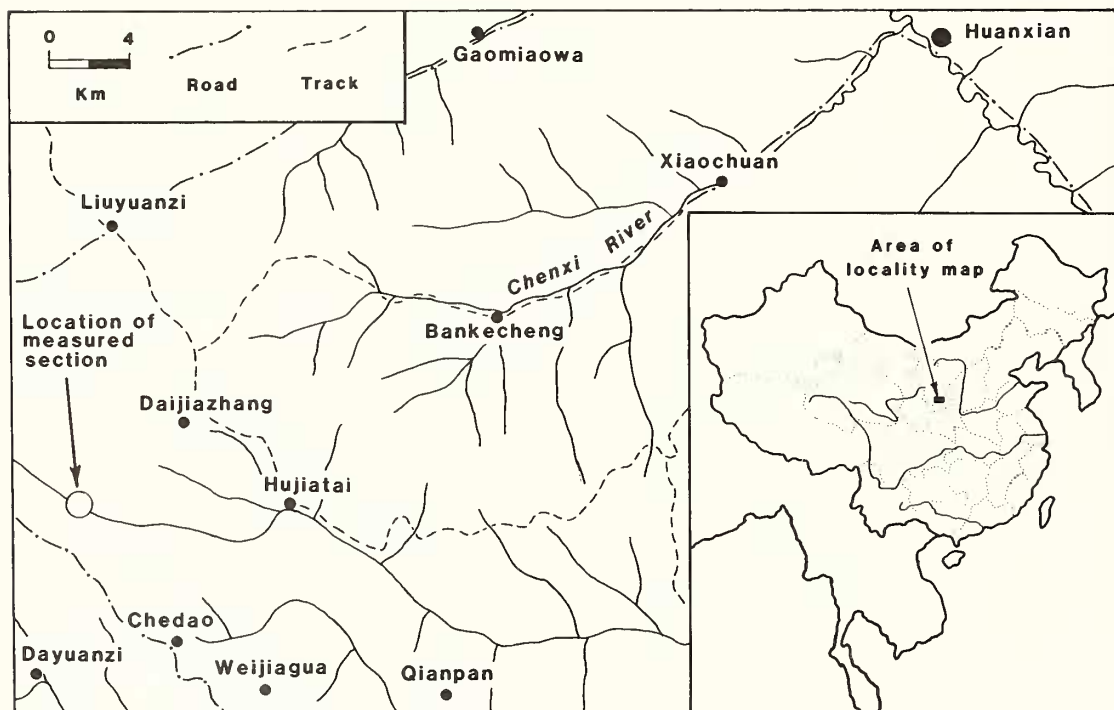
Trilobites include: *Birmanites* sp. indet., *Bulbaspis* sp. indet., *Cyphoniscus* cf. *socialis* Salter, 1853, *Geragnostus* aff. *longicollis* (Raymond 1925), *Glaflurina* sp., *Hammatocnemis kanlingensis* Zhang, 1981, *H. obsoletus* sp. nov., *Lonchodomas nanus* Zhou in Zhou *et al.* 1982, *Microparia (Quadrropyge) chedaoensis* sp. nov., *Peraspis obscura* sp. nov., *Rorringtonia* sp., *Shumardia tarimuensis* Zhang, 1981, *Stenopareia* sp. indet. and *Telephina* sp. Of these *Peraspis obscura* outnumbers every other species, and *Stenopareia* is represented by only one abraded cranidium.

The single graptolite taxon found in association with the trilobites was identified by Ni Yunan (Nanjing Institute of Geology and Palaeontology) as *Dicellograptus sextans exilis* Elles and Wood, 1904, indicative of the *Nemagraptus gracilis* Biozone, now considered correlative with the middle and upper Llandeilo Series and

basal Caradoc Series (Williams *et al.* 1972). *Microparia* (*Quadrropyge*) is known from Caradoc strata of Taojiang, Hunan, considered as part of the slope area of the Yangtze Platform in the Ordovician, and probably also from southern Scotland (J. K. Ingham, pers. comm.). *Rorringtonia* occurs in the Llandeilo to early Caradoc of England (Shropshire), Wales, and Norway. *Lonchodomas nanus* is known from the topmost Pingliang Formation (*Nemagraptus gracilis* Biozone) of Ningxia, north-west China. None of these records contradicts the present graptolite evidence.

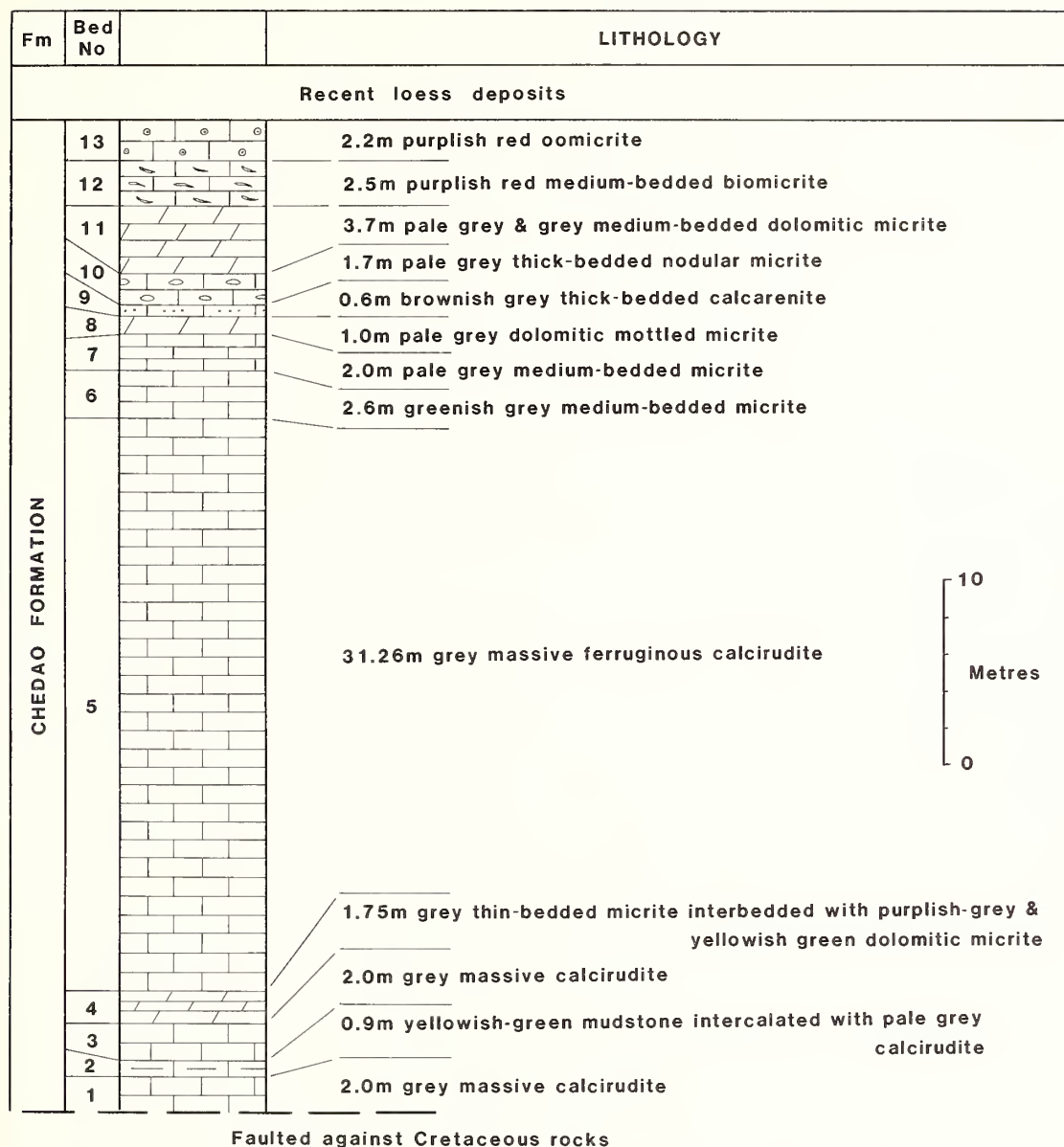
Macrofossils from Bed 12

The trilobite fauna is rich in *Nileus huanxianensis* Zhou and *Pseudostygina lepida* Zhou both in Zhou *et al.* 1982. Other taxa include: *Arthrorhachis* cf. *tarda* (Barrande 1846), *Birmanites* aff. *asiaticus* (Petrunkina in Repina *et al.* 1975), *Cyclopyge* cf. *recurva* Lu in Wang *et al.*, 1962, *Ovalocephalus kelleri* Koroleva, 1959, *Ischyrophyma?* *zhigiangi* sp. nov., *Lichas* aff. *laciniatus* (Wahlenberg 1818), *Lyrropyge?* *gaohuensis* (Zhou in Zhou *et al.* 1977), *Paraphillipsinella globosa* Lu in Lu and Chang 1974, *Paratiresias turkestanicus* Petrunkina in Repina *et al.* 1975, *Phorocephala quadrata* sp. nov., *Stenopareia* aff. *bowmanni* (Salter 1848), *Telephina convexa* Lu, 1975 and *Xenocybe?* sp.



TEXT-FIG. 1. Outline maps showing location of the described measured section.

Associated cephalopods, identified by Zou Xiping (Nanjing Institute of Geology and Palaeontology) as species of *Sinoceras* and *Michelinoceras*, constitute a fauna that, according to Lai *et al.* (1982, pp. 66, 229) is identical with the *Sinoceras chinense* assemblage of the Pagoda Formation in the Yangtze region, and the presence of the trilobites *Cyclopyge recurva* and *Paraphillipsinella globosa* in the Pagoda Formation supports the evidence from the cephalopods. A Caradoc age for the Pagoda Formation has been suggested on the basis of both faunas and regional stratigraphic context (Lu 1959; Chang 1960; Lu *et al.* 1976; Lai *et al.* 1982; Zheng *et al.* 1982).



TEXT-FIG. 2. Measured section of the type Chedao Formation, showing bed numbers referred to in the text.

RELATIONSHIPS OF THE TRILOBITES

The composition of both trilobite assemblages approximates to that of the Nileid Association proposed by Fortey (1975*b*) on the basis of the Spitzbergen succession; this suggests that the Huanxian area formed part of the (now) western slope of the North China carbonate platform. The Huanxian trilobites, including all listed from Beds 4 and 12, may be divided into three groups:

1. Widespread or pelagic genera that occurred in environments from shallow platform to slope. These include *Phorocéphala*, *Birmanites*, *Cyclopyge*, *Lyrpyge*, *Telephina* and *Hammatocnemis*.

2. Genera such as *Nileus*, *Peraspis*, *Bulbaspis*, *Microparia* (*Quadrropyge*) and *Shumardia* (s.s.) that are restricted to, or found predominantly in, the Nileid Association or occur in equivalent slope facies. Several species from Bed 4 are of typical North American type and closely resemble forms from the Middle Table Head Formation (Whittington 1965) of western Newfoundland; they include *Geragnostus* aff. *longicollis*, *Shumardia tarimuensis* (closely allied to *S. granulosa*, type species of the genus) and *Peraspis obscura*. According to Fortey (1975b, p. 344) the Table Head trilobite assemblage is similar to that of the Nileid Association. In Shropshire *Rorringtonia* occurs in dark, graptolitic shales with, *inter al.*, *Cnemidopyge*, *Selenopeltis*, *Ogygiocarella*, and *Spirantyx* (Whittard 1966, pp. 299–302, 306). In central Wales the genus is known from dark, graptolitic mudstones with various cyclopygids, *Geragnostus*, *Barrandia*, *Ogygiocarella*, and *Ogyginus*; these associations suggest a deep water, offshore environment (Owens 1981, p. 91).

3. Genera that may have originated from nearby carbonate mounds (or 'reefs') include *Cyphoniscus*, *Paratiresias*, *Glaphurina*, and *Ischyrophyma*? Isocolid trilobites are more typical of a carbonate mud-mound facies (Dean 1971, p. 52), as are *Glaphurina* and *Ischyrophyma* (Fortey 1975b; Mikulic 1980). *Stenopareia* and probably *Lichas* may also be mound-derived allochthonous forms, judging by faunas described from Ashgill carbonate mounds in central Sweden (Warburg 1925, 1939), northern England and eastern Ireland (Dean 1971, 1974, 1978).

Although the trilobite assemblages from Beds 4 and 12 are both indicative of a slope facies, that of Bed 4 suggests deeper water than that of Bed 12. Only 14% of trilobites from the graptolite-bearing strata of Bed 4 belong to what Fortey (1975b) termed the Illaenid Association, which includes the carbonate mound facies, but in Bed 12 the corresponding figure is 33%.

Trilobites from Bed 12 are closely related to late Caradoc to Ashgill faunas in Central Asia that include the following forms:

Arthrorhachis cf. *tarda*, *Birmanites* aff. *asiaticus*, *Xenocybe*? sp., *Lichas* aff. *laciniatus*, *Ovalocephalus kelleri*, and *Paratiresias turkestanicus*. The Bed 12 assemblage also bears a great resemblance to the Caradoc to early Ashgill faunas of the Yangtze Platform, as indicated by the following, or closely allied species: *Arthrorhachis* cf. *tarda*, *Lyrropyge*? *gaoluensis*, *Cyclopyge* cf. *recurva*, *Paraphillipsinella globosa*, and *Telephina convexa*. The assemblage from Bed 4 exhibits mixed affinities and includes several trilobites of North American type (see above), though *Birmanites*, *Bulbaspis*, and *Hammatocnemis* indicate Asiatic affinities.

One of the results of the present work is additional evidence that many Ordovician trilobite genera had long stratigraphic ranges, and that some once thought to be very short-ranging persisted much longer when the appropriate environments were available. Examples are *Arthrorhachis*, *Birmanites*, *Geragnostus*, *Nileus*, *Phorocephala*, and *Shumardia*, all of which persisted from the Tremadoc to the Ashgill, and *Hammatocnemis* and *Telephina*, which ranged from Arenig to Ashgill. *Cyphoniscus*, once regarded as a typical Ashgill isocolid, occurs at our section in the Llandeilo or lowest Caradoc (at one locality in eastern Canada it is known also from lowest Silurian beds; Dean 1972). *Lyrropyge*, founded on material from the Arenig of Spitsbergen, is here recorded from the Caradoc; and *Peraspis*, recorded previously from the Arenig to Llanvirn, has its range extended into the Caradoc on the basis of *P. obscura*, its youngest known species, in Bed 4. The long range of trilobite genera found predominantly in carbonate mound facies is related to persistence of the tropical shelf-edge habitat (Fortey 1980b).

A particular problem of Ordovician trilobite generic assemblages concerns autochthonous elements of the Nileid Association, particularly in rocks of Arenig–Llanvirn age such as the Table Head Formation of western Newfoundland. The subject was discussed by Ross (1970) in an account of the problems involved in defining the Whiterock Stage in western USA. Ross and Ingham (1970), after finding a trilobite generic assemblage of 'Whiterock' type in lowest Caradoc strata in the Girvan area, Scotland southern, noted the very widespread occurrence of what they termed the 'Toquima-Table Head Faunal Realm' (named for areas in Nevada and western Newfoundland). Many of the genera in their 'faunal realm' had extended ranges but were adapted to a particular environment and palaeogeographic setting, peripheral to Laurentia in the Ordovician and close to

the transition from miogeosynclinal to eugeosynclinal facies; distribution and migration of the trilobites would follow dispersal of the appropriate facies belts. Further evidence of this concept is provided by the Chedao Formation trilobites, so that some genera documented particularly from the early Ordovician persist as late as the Caradoc, while others predate genera thought at one time to be characteristic of the Ashgill.

SYSTEMATIC PALAEOONTOLOGY

Terminology is essentially that Harrington *et al.* (in Moore 1959, pp. O117–O126); additions are lunette (Whittington 1954, p. 139) for a crescent-shaped area in the axial furrows of some illaenids; eye socle (Shaw and Ormiston 1964); and baccula (Öpik 1967, p. 53).

Taxa are arranged in Treatise order (Moore 1959), additions and modifications are as follows: Scharyiinae are included in the Aulacopleuridae (Thomas and Owens 1978), Phillipsinellidae are considered to be related to the Styginidae (Bruton 1976; Lane and Thomas 1983). Metagnostidae is used instead of Geragnostidae, following Fortey (1980a). The Hammatocnemidae Kielan, 1960 is regarded as an independent family following Apollonov (1974) and Lu (1975); a more recent study (Lu and Zhou 1979) shows that it is closer to the cheirurids than to the phacopids.

Specimens described and listed in this account are deposited at institutions designated by the following abbreviations: NI, Nanjing Institute of Geology and Palaeontology, Academia Sinica; XTR, Regional Geological Survey Team of Xinjiang; XITr, Xi'an Institute of Geology and Mineral Resources; II IV, Yichang Institute of Geology and Mineral Resources; IGG, Institute of Geology and Geophysics, Siberian Branch of the Academy of Sciences of the U.S.S.R. Figured specimens were first blackened with ink and then coated with magnesium oxide before being photographed.

Family METAGNOSTIDAE Jaekel, 1909

Subfamily METAGNOSTINAE Jaekel, 1909

Genus ARTHRORHACHIS Hawle and Corda, 1847

Type species. *Battus tardus* Barrande, 1846, from the Králův Dvůr Formation (Ashgill) of Liomysl, near Zdice, Czechoslovakia.

Remarks. We follow Fortey (1980a) in restricting the genus *Trinodus* to the holotype of the type species, *T. agnostiformis* M'Coy, 1846.

Arthrorhachis cf. *tarda* (Barrande, 1846)

Plate 58, figs. 3, 4

Figured specimens. One cephalon (NI 80590) and one pygidium (NI 80591) from Bed 12.

Description and remarks. *Arthrorhachis tarda* and allied forms have been recorded from the Ashgill of Bohemia (Barrande 1852), Poland (Kielan 1960), South Wales (Dean 1971), North Wales (Whittington 1968), northern England (Ingham 1970), Kazakhstan (Apollonov 1974), and Uzbekistan (Abdullaev 1972), and from the late Caradoc to Ashgill of Norway (Owen and Bruton 1980). The lectotype of *A. tarda*, refigured by Pek (1977, pl. 8, fig. 2), and topotypes described by Whittington (1950) are comparable with the present form but the latter has a wider (tr.) glabella, in which respect it is similar to specimens described by Whittington (1968) and by Dean (1971). Traces of five pairs of muscle scars on the glabella posterior to the glabellar furrow are comparable with those on a well-preserved specimen of *A. danica brevis* Fortey (1980a, pl. 2, fig. 10). Patterns of glabellar furrows and muscle scars are not known in *A. tarda* but traces on a cranidium figured by Whittington (1968, pl. 29, fig. 10) seem compatible with those of the present form.

As Owen and Bruton (1980) concluded, species of *Arthrorhachis* (as *Trinodus*) from the late Ordovician of Europe need to be revised, as do species from the Caradoc to Ashgill of China and central Asia. In specimens of *A. cf. tarda* from the Ashgill of Ireland (Dean 1971, p. 7) the length of the glabella varied from 63 % to 70 % that of the cephalon, while the pygidial axis was 38 % to 50 % of the pygidial length. In *A. aff. tardus* from the Upper Chasmops Limestone of Norway (Owen and Bruton 1980) the corresponding figures were 55 % and 55 %. *Trinodus subtardus* Petrunina in Repina *et al.* 1975, *Trinodus cylindricus* Chen in Li *et al.* 1975, *Trinodus corrugatus* Chen in Li *et al.* 1983 and *Trinodus carinatus* Ju in Qiu *et al.* 1983 fall within the range of

variation above, and other characters are also similar to those of *A. tarda*. All these species are allied to, and may even be referable to, the type species of *Arthrorhachis*.

Genus GERAGNOSTUS Howell, 1935

Type species. Agnostus sidenbladhi Linnarsson, 1869 from the late Tremadoc (*Apatokephalus serratus* Zone) of Mossebo, Västergötland, Sweden (see Tjernvik 1956, pl. 1, figs. 5 and 6).

Geragnostus aff. *longicollis* (Raymond 1925)

Plate 58, figs. 1, 2, 5

Figured specimens. Two cephalon (NI 80587, 80588) and one pygidium (NI 80589) from Bed 4.

Remarks. The cephalon strongly resembles that of *Arthrorhachis tarda* (Barrande) but shows an additional tiny basal glabellar tubercle and a more flattened border. The pygidial axis occupies 70 % of the pygidial length and has a tiny median tubercle near the tip. The posterior axial segment, with length about half that of the axis, is much longer than in *Arthrorhachis tarda* and the Chinese form is referred to *Geragnostus* rather than *Arthrorhachis*. As pointed out by Dean (1966) and Fortey (1980a) features such as relative length of pygidial axis are insufficient to separate these genera and Dean (1966) suggested that *Geragnostus* may prove eventually to be a junior subjective synonym of *Arthrorhachis* (as *Trinodus*).

The present form recalls *G. longicollis* (Raymond 1925, p. 12, pl. 1, fig. 5; Whittington 1965, p. 301, pl. 1, figs. 1–12, 14, 16, 17) from the Table Head Formation (approx. lower Llanvirn) of western Newfoundland, and an allied form from the north-western Yukon described by Dean (1973, p. 2, pl. 1, figs. 1–6). *G. chusus* Whittington (1963, p. 28, pl. 1, figs. 1–17), from the Llanvirn of Lower Head, western Newfoundland, and *G. symmetricus* Zhou (in Zhou *et al.* 1982, p. 215, pl. 57, figs. 2 and 3) from the Llanvirn of north-west China differ only in the more narrowly rounded tip of the pygidial axis and the narrower cephalic and pygidial border furrows. These three species are very alike and, as discussed by Whittington (1965, pp. 301, 302) and Zhou (in Zhou *et al.* 1982, p. 216), distinguishable only on the basis of minor characters. The well-rounded anterolateral cephalic and posterolateral pygidial angles suggests that the present form is closest to *G. longicollis*.

The type species of *Geragnostella* Kobayashi, 1939, *Agnostus tullbergi* Novák, 1883 from the Šárka Fm. (Llanvirn) of Bohemia and redescribed by Pek (1977), exhibits an *Arthrorhachis*-*Geragnostus* type of glabella with indications of a V-shaped glabellar furrow in front of the median tubercle. Its pygidium is, as noted by Pek, characterized by the long, narrow posterior axial ring but agrees more or less with that of the present form. The length of the pygidial axis is variable in agnostids (Fortey 1980a, p. 26) and the relative length of the posterior axial ring may vary even within a species, as Whittington (1963, p. 29) pointed out for *Geragnostus chusus*. The great similarity between *Geragnostella tullbergi* and our species supports the view (Dean 1966, p. 273) that *Geragnostella* may be a junior subjective synonym of *Geragnostus*.

EXPLANATION OF PLATE 58

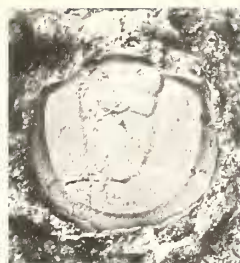
Figs. 1, 2, 5. *Geragnostus* aff. *longicollis* (Raymond, 1925). Bed 4. 1, pygidium, NI 80587, $\times 10$. 2, cephalon, NI 80588, $\times 10$. 3, cephalon, NI 80589, $\times 6$.

Figs. 3 and 4. *Arthrorhachis* cf. *tarda* (Barrande, 1846). Bed 12. 3, cephalon, NI 80590, $\times 12$. 4, pygidium, NI 80591, $\times 12$.

Figs. 6–9, 13. *Shumardia tarimuensis* Zhang, 1981. Bed 4. 6, cranidium, NI 80592, $\times 12$. 7, pygidium, NI 80593, $\times 12$. 8, cranidium, NI 80594, $\times 12$. 9, pygidium, NI 80595, $\times 12$. 13, pygidium, NI 80596, $\times 12$.

Figs. 10, 12, 14–19. *Phorocephala quadrata* sp. nov. Bed 12. 10, 14, pygidium; dorsal and right lateral views, holotype, NI 80597, $\times 5$. 12, juvenile cranidium, paratype, NI 80598, $\times 12$. 15 and 16, cranidium, dorsal and right lateral views, paratype, NI 80599, $\times 8$. 17, pygidium, paratype, NI 80600, $\times 6$. 18, cranidium, paratype, NI 80601, $\times 8$. 19, cranidium, paratype, NI 80602, $\times 10$.

Fig. 11. *Telephina convexa* Lu, 1975. Bed 12. Cranidium, NI 80603, $\times 5$.



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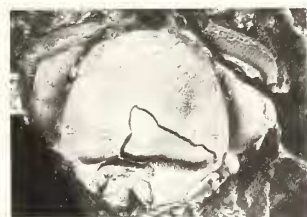
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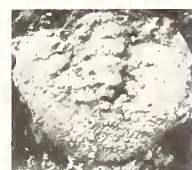
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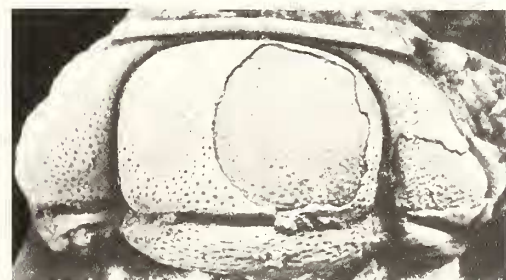
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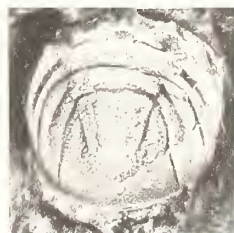
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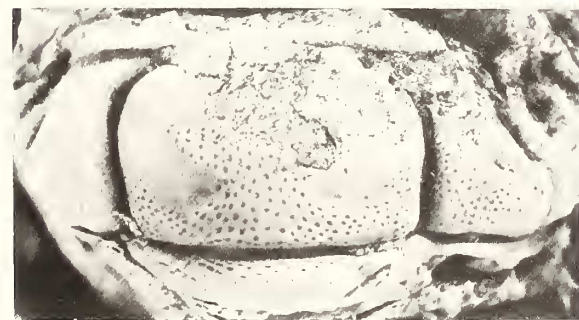
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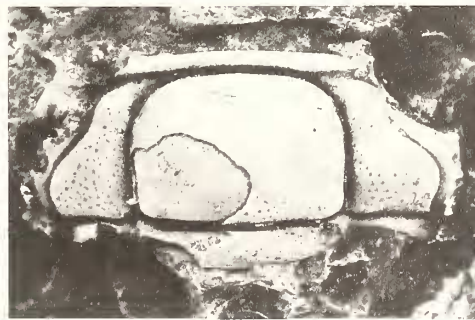
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19

Family SHUMARDIIDAE Lake, 1907

Genus SHUMARDIA Billings, 1862

Type species. *Shumardia granulosa* Billings, 1862 from the *Shumardia* Limestone (lower Llanvirn) of Lévis, Quebec, Canada.

Shumardia tarimuensis Zhang, 1981

Plate 58, figs. 6-9, 13

1981 *Shumardia tarimuensis* Zhang, p. 163, pl. 61, figs. 7 and 8.

Diagnosis. Species of *Shumardia* without posterolateral glabellar lobe. Pygidium stout with narrow (tr.) axis.

Holotype. XTR 131, incomplete dorsal shield (Zhang 1981, pl. 61, fig. 7) from the Saergan Formation (Llanvirn to lower Caradoc) of Kanling, Keping County, Zinjiang, China.

Figured specimens. Two cranidia (NI 80592, 80594) and three pygidia (NI 80593, 80595, 80596) from Bed 4.

Description. Cranidium twice as broad as long, semicircular in outline, gently convex, declined slightly both anteriorly and laterally. Glabella with outline like arrow-head occupies two-thirds length and one-quarter posterior width of cranidium; it is convex, highest at midpoint of posterior margin, from which it declines forwards. Anterior part of glabella V-shaped frontally, with pair of prominent, tear-shaped anterolateral lobes, the overall width of which is about one-and-a-half times basal glabellar width; posterior half of glabella tapers forwards into deep furrows at base of anterolateral lobes. Occipital ring transversely convex with length (sag.) one-fifth that of cranidium; its posterior margin is bowed backwards immediately behind posteriorly placed median tubercle; occipital furrow deep. Axial furrows deep and broad beside posterior half of glabella but deep and narrow anteriorly. Preglabellar field narrow (sag.) with deep mesial notch. Posterior border widens (exsag.) distally; posterior border furrow is narrow proximally and dies out distally.

Pygidium triangular in outline, 1.2 times wider than long. Conical axis occupies little more than half length of pygidium and one-third its breadth measured across anterior margin; there are four axial rings and small rounded terminal piece, all delimited by deep ring furrows, in addition to articulating half-ring. Axial furrows deep and wide. Pleural lobes exhibit up to five pairs interpleural furrows that decrease in size posteriorly; first pair extend near facets but fifth pair appear only as short indentations. No pleural furrows visible except first pair, which are deep and transverse. Surface granular except for pygidial border, which is smooth.

Remarks. Although *Conophrys* Callaway, 1877, type species *C. salopiensis* Callaway from the Upper Tremadoc of Shropshire, and *Shumardia* are sometimes regarded as possibly distinct (e.g. Dean 1973, p. 8) they have also been considered congeneric (Poulsen in Moore 1959, p. O245). Judging from the long triangular pygidium of *S. tarimuensis* we consider it to be a typical *Shumardia*, and species with similar pygidia include not only the type species *S. granulosa* but also *S. dicksoni* Moberg and Segerberg, 1906 and *S. lacrima* Koroleva, 1964. Of these the Chinese species bears the greatest resemblance to *S. granulosa* (see Whittington 1965, p. 327, pl. 16, figs. 1-17) but differs in the absence of posterolateral glabellar lobes, the less acutely pointed front of the glabella, and the relatively shorter pygidium with narrower axis.

Family KOMASPIDIDAE Kobayashi, 1935

Genus PHOROCEPHALA Lu in Lu *et al.*, 1965

Type species. *Phorocephala typa* Lu in Lu *et al.* 1965, from the Siliangssu Formation (upper Arenig) of Liangshan, Shaanxi Province, China.

Remarks. Tripp (1976, p. 423) suggested that *Carrickia* Tripp, 1965, type species *C. pelagia* Tripp, 1965 from the Caradoc of Scotland, is a junior synonym of *Phorocephala*. We tentatively consider both genera as synonymous, following Zhou, Yin, and Tripp (1984, p. 23).

On the basis of stratigraphic occurrence and the presence or absence of a preglabellar field, described species of *Phorocephala* fall into two groups:

1. Upper Tremadoc to Llandeilo species with preglabellar field. These include: *P. similis* Lu, 1975; *P. genalata* Lu, 1975; *P. shizipuensis* Yin in Yin and Lee 1978; *P. gracilis* Zhou in Zhou *et al.* 1982; *Bathyurus mansuyi* Reed, 1917; *Leioestegium?* cf. *mansuyi* (Reed) of Weber 1948; *P. typa* Lu in Lu *et al.* 1965; *Carrickia setoni* Shaw, 1968; *Goniophrys breviceps* (Billings 1865); *Carrickia* sp. 1 of Ross 1972, p. 29, pl. 10, fig. 19; undetermined genus and species A of Ross 1951, pl. 18, figs. 21, 23, 24; and, questionably, *Bathyurus breviceps* Billings, 1865.

2. Caradoc to Ashgill species without preglabellar field. These include: *Carrickia pelagia* Tripp, 1965; *C. athleta* Dean, 1971; *C. pinguimitra* Chatterton and Ludvigsen, 1976; *C. ulugšana* Petrunina in Repina *et al.*, 1975; *P. quadrata* sp. nov.; *Phorocephala* sp. of Owen and Bruton 1980; and gen. indet. of Abdullaev (1972, pl. 46, figs. 9–11).

In earlier species such as *P. genalata* Lu (from the middle Arenig of Hubei Province, China) and the unnamed species of Ross (1951, from letter Zone F of the Canadian Series in north-eastern Utah, USA) the glabella is relatively smaller and the palpebral lobes shorter than in younger species.

Morphological changes that take place during the ontogeny of *Phorocephala*, as exemplified by *P. pinguimitra* and described by Chatterton (1980, p. 31), include the medial disappearance of the preglabellar field, and the increase in relative size of glabella (tr. and sag.) and palpebral lobes (exsag.). Similar changes would have taken place during the phylogeny of *Phorocephala*.

Phorocephala quadrata sp. nov.

Plate 58, figs. 10, 12, 14–19

Derivation of name. Latin—*quadratus*, *a*, *um*, square, referring to the shape of the combined glabella and occipital ring.

Holotype. Pygidium, NI 80597 (Pl. 58, figs. 10 and 14) from Bed 12.

Paratypes. Four cranidia (NI 80598, 80599, 80601, 80602) and one pygidium (NI 80600) from Bed 12.

Diagnosis. *Phorocephala* species with cranidium about half as long as wide, and transversely straight anterior border; glabella large, subquadrate, its width about half that of cranidium. Pygidium as wide as long, composed of three segments; axis trapezoidal in cross-section.

Description. Cranidium about twice as wide as long, trapezoidal in plan, widest across base. Glabella convex, subquadrate, defined by deep axial furrows, rounded anterolaterally, its width about half that of cranidium. Occipital ring wider (tr.) than base of glabella, with length (sag.) less than one-fifth that of cranidium, gently convex posteriorly in plan, becoming slightly shorter (exsag.) abaxially. Occipital furrow deep, broad, straight. Anterior border straight, well defined by deep anterior border furrow, uniformly narrow (sag.), upturned. Posterior border narrows (exsag.) laterally, bounded by deep, broad posterior border furrow. Preglabellar field absent in mature cranidia. Fixigenae wide posteriorly, narrow forwards, moderately convex, declined abaxially. Palpebral lobes separated from fixigenae by narrow, deep palpebral furrows and extend forwards from just in front of posterior border furrow almost to anterior border furrow; they are widest (tr.) opposite centre of glabella, converge gently forwards, at the same time becoming steadily narrower, and posterior portions are strongly convex abaxially. Anterior branches of facial suture very short, strongly convergent frontally; posterior branches short, divergent posteriorly. Surface of exoskeleton densely covered with pits that are circular except on occipital ring, where transversely elongated. Two pairs muscle scars represented by smooth, unpitted patches on external surface; anterior pair (2p) triangular, narrow adaxially, located on anterolateral margin and extend adaxially backwards; posterior (1p) pair subrectangular, widen (exsag.) abruptly adaxially, begin in axial furrows at points just in front of line through centre of glabella, and run subparallel to 2p muscle scars; in large specimens the 1p scars deepen and coalesce with pair of apodemal pits (at adaxial extremities). A juvenile cranidium (Pl. 58, fig. 12) has a narrow (sag.) preglabellar field and the glabella is subspherical.

Pygidium subelliptical, as long as wide, strongly convex transversely. High, tapered axis three-quarters as wide as long, and occupies about two-thirds anterior pygidial width; it consists of two axial rings, terminal piece, and articulating half-ring. Axis is subtrapezoidal in cross-section, divided into three bands by two closely spaced, subparallel, longitudinal ridges. Medial part is flat; the lateral bands are steeply declined abaxially; and in large specimens two longitudinal rows of nodes are arranged along the ridges. First two axial rings uniformly long (sag.), arched forwards in plan, well defined by narrow ring furrows; third ring visible, though faintly demarcated, on large specimens, and tip of axis slopes down posteriorly to merge

smoothly with postaxial area. Axial furrows narrow, weaker posteriorly. Pleural lobes include three pairs of pleurae that extend posteriorly, but only anterior two pairs well defined. Three pairs deep, short (tr.) pleural furrows die out at midpoints of pleurae, each of which is divided into raised anterior and depressed posterior pleural bands. Three pairs of interpleural furrows present; anterior two pairs distinct, narrow, and reach pygidial margin; posterior pair wide, shallow, and disappear before attaining tip of axis. Articulating facets broad (exsag.), and decline from fulcra sited near front ends of axial furrows. Pygidial border apparently absent, but may be represented by narrow strip at margin. Surface of exoskeleton densely granulate.

Remarks. The new species generally resembles *P. pinguimitra* (Chatterton and Ludvigsen 1976, p. 44, pl. 17, figs. 1–50) from the Chazy of north-west Canada but in the latter the anterior border of the cranidium is arched forwards in plan, the pygidium is wider (tr.), with only two segments, and the pygidial axis is shorter (sag.), semicircular in cross-section, with sigmoidal ring furrows. *P. athleta* (Dean 1971, p. 48, pl. 23, figs. 2–9; pl. 24, figs. 1–4, 6, 8, 11), from the Ashgill of Ireland, is distinguished from *P. quadrata* by its frontally rounded glabella, the anterior border that is curved backwards abaxially, and the wider pygidium with two segments and a stouter axis that is semicircular in cross-section.

Family TELEPHINIDAE Marek, 1952

Genus TELEPHINA Marek, 1952

Type species. *Telephus fractus* Barrande, 1852, from the Králův Dvůr Formation (Ashgill) and Nučice Beds (late Caradoc) of Bohemia.

Telephina convexa Lu, 1975

Plate 58; fig. 11; Plate 59, figs. 1 and 4

- 1975 *Telephina* (*Telephina*) *convexa* Lu, p. 294, pl. 2, figs. 25 and 26.
- 1977 *Telephina* (*Telephina*) *convexa* Lu; Zhou *et al.*, p. 190, pl. 56, fig. 6.
- 1978 *Telephina* (*Telephina*) *convexa* Lu; Xia, p. 158, pl. 28, fig. 9.
- 1983 *Telephina* (*Telephina*) *convexa* Lu; Qiu *et al.*, p. 170, pl. 57, fig. 14.

Diagnosis. *Telephina* species with strongly angulate palpebral lobes. Glabella and occipital ring covered with web-like raised lines and scattered coarse granules on external surface, and coarse granules on exfoliated surface.

Holotype. Cranidium, NI 16419, figured Lu (1975, pl. 2, figs. 25 and 26), from the Linhsiang Formation (early Ashgill) of Fenxiang, Yichang, Hubei Province, eastern China.

Figured specimens. Two cranidia (NI 80603, 80604) from Bed 12.

Remarks. The smaller cranidium (Pl. 58, fig. 11) differs from the larger in that the preglabellar area is narrower and the glabella has a pair of shallow impressions. In the light of morphological changes during the ontogeny of *T. bicuspis* (Angelin 1854) demonstrated by Nikolaisen (1963, pp. 365–366), we consider differences between our two specimens to be due to differences in size.

The external surface is covered with raised lines in a multiple web-like pattern; individual lines radiate from coarse granules on the glabella and occipital ring and from fine and scattered coarse granules on the fixigenae and palpebral lobes. The exfoliated surface shows low granules that are well marked on glabella and occipital ring. Anterior border and frontal spines exhibit raised lines parallel to their anterior margins. The pattern of ornamentation is very similar to that of *T. americana* (Billings 1865) (see Whittington 1965, p. 367, pl. 37; pl. 38, figs. 7–9, 11) and of *T. sp.* of Whittington (1965, p. 371, pl. 38, figs. 1–6, 18), both from the Table Head Formation (Llanvirn) of western Newfoundland, but the Canadian species have fainter granules on the internal mould.

The holotype of *T. convexa* is an internal mould and the surface sculpture is not preserved. The occipital tubercle and small spine seen on the holotype are not preserved on the present material, but otherwise there is good agreement. As noted by Lu (1975) the American species *T. gelasinosa* (Ulrich in Butts 1926) (see Ulrich 1930, p. 26, pl. 7, figs. 12–14), from the middle Ordovician of Alabama, may be closely related to *T. convexa* but differs in the rounded anterolateral angles of the cranidium and the densely granular surface of the exoskeleton.

T. convexa is very similar to *T. nikolaiseni* Apollonov (1974, p. 14, figs. 10, 11, 14) from the Ashgill of Kazakhstan, and the two may prove synonymous, but specimens of the Russian species are too poorly preserved to show the surface ornamentation. According to Apollonov's description the cranidium of *T. nikolaiseni* is covered with what he called 'capillary', but it is difficult to see whether or not granules are present and what the pattern of striae is. We refer the Chinese specimens to *T. convexa* until further material of *T. nikolaiseni* is available.

Telephina sp.

Plate 59, figs. 2 and 5

Figured specimen. Cranidium NI 80605, from Bed 4.

Remarks. This form may represent a new species but the available material is insufficient. The specimen has a pair of extraordinarily thick, tear-like cephalic frontal spines. In this respect it somewhat resembles *T. convexa* but differences include: the more tapered glabella with much denser granules on the surface; the more rounded anterolateral corners of the cranidium; and the three pairs of granulose glabellar muscle scars, the anterior two pairs of which are discrete instead of confluent. Similar features are found in the American Caradoc species *T. gelasinosa* (Ulrich in Butts 1926) but the latter has a pair of more slender frontal spines and its palpebral lobes are semicircular in plan. In the outline of the glabella and size of the fixigenae the Chinese specimen is comparable with *T. angulata* Yi (1957, p. 554, pl. 3, fig. 4) from the Yangtze region and *T. versa* Nikolaisen (1963, p. 379, pl. 3, figs. 5–10) from Scandinavia, both of Llandeilo age, but in the two last-named the glabella is relatively shorter (sag.) (length = 0.8 of its width, compared with 0.88), there are more scattered granules on glabella and occipital ring, and the frontal spines are smaller. *T. versa* also has less angulate palpebral lobes than *T. angulata*, and in this respect seems closer to our specimen.

Family GLAPHURIDAE Hupé, 1953

Genus GLAPHURINA Ulrich, 1930

Type species. *Glaphurina lamottensis* Ulrich, 1930, from the Upper Chazy (approx. Llandeilo) of Isle La Motte, Vermont, USA.

Glaphurina sp.

Plate 59, fig. 8

Figured specimen. Cranidium, NI 80612, from Bed 4.

Remarks. The single, imperfect cranidium closely resembles *G. lamottensis* Ulrich (1930, p. 45, pl. 8, figs. 14–16; Shaw 1968, p. 29, pl. 8, figs. 10–15; pl. 9, figs. 1–3, 5–8) in the following characters: wide cranidium, broadly and evenly rounded anteriorly; deeply incised longitudinal posterior glabellar furrow continuous with shallow, oblique anterior furrow; deep axial furrows; narrow (sag.), steeply upturned anterior border; divergent anterior branches of facial suture; large posterior area of fixigenae; and surface densely covered with tubercles of two sizes. It differs in having a very narrow (sag.) preglabellar field like that of, for example, the Llanvirn species *G. granulosa* Zhou in Zhou *et al.* (1982, p. 254, pl. 63, fig. 15a, b) from north-west China and the early Caradoc species *G. dulanensis* Weber, 1948 (see Chugaeva 1958, p. 75, pl. 8, figs. 13–15; non Weber 1948, p. 55, pl. 8, figs. 22 and 23) from Kazakhstan.

Family ASAPHIDAE Burmeister, 1843

Subfamily ASAPHINAE Burmeister, 1843

Genus BIRMANITES Sheng, 1934

Type species. *Ogygites birmanicus* Reed, 1915, from the Hwe Mawng Beds (lower Ordovician) of Hwe Mawng and Hpakhí, northern Shan State, Burma.

Remarks. *Opsimasaphus* Kielan, 1960 differs from *Pseudobasiliscus* Reed, 1931 mainly in the longer preglabellar area, and the narrower axis and pygidial doublure (cf. Kielan 1960, p. 75). These characters, in turn, agree well with those of *Birmanites*, of which we consider *Opsimasaphus* a junior subjective synonym. Both genera may eventually prove synonymous with *Ogygites* Tromelin and Lebesconte, 1876, as discussed by Zhou, Yin and Tripp (1984, p. 17).

Birmanites aff. *asiaticus* (Petrunina in Repina *et al.* 1975)

Plate 59, figs. 7, 10, 11, 13–15

Figured specimens. Two cranidia (NI 80607, 80611) and three pygidia (NI 80608–80611) from Bed 12.

Description. Cranium of low convexity. Glabella subparallel-sided, broadly rounded frontally, three-quarters as long as wide; 1p furrows directed inwards and backwards, distinct anteriorly; 1p lobes triangular; 2p furrows faint, short, close to 1p abaxially, directed anteriorly; prominent median tubercle close behind occipital furrow; median ridge in front of frontal glabellar lobe. Occipital ring slightly convex transversely, with straight posterior margin; occipital furrow shallow. Axial furrows wide and shallow. Narrow, elongate bacculae sited opposite 1p lobes. Palpebral lobes semicircular in outline, narrow (tr.), weakly defined by obscure palpebral furrows; length one-fifth that of glabella, their anterior extremities opposite adaxial ends of 1p furrows and at one-third cranial length from posterior margin. Preglabellar area slightly depressed, turned up frontally into weakly defined anterior border, its length one-third that of glabella. Anterior branches of facial suture diverge forwards for short distance, then curve forwards to anterior border furrow, and finally turn inwards to meet medially at obtuse angle; posterior branches sinuous and divergent. Posterior areas of fixigenae narrow (exsag.) with uniformly wide border, well defined by border furrow.

Pygidium semielliptical in outline, about three-fifths as long as wide; anterolateral facets occupy half width pleural lobes. Convex axis, one-third to one-fourth length and one-fourth width of pygidium, tapers backwards, divided into seven to eight axial rings and small rounded terminal piece; transverse ring furrows shallow on external surface, distinct on internal mould; axial furrows broad. Pleural lobes flat with five pairs ribs defined by pleural furrows, only first pair of which is deeply incised. Border furrow obscure. Doublure extends to midlength of pygidium and occupies half width of pleural lobes anteriorly.

Surface covered with irregular, fine, raised lines, subparallel to margins, and densely arranged only on preglabellar area and that part of pygidial border above the doublure.

Remarks. The cranium is characterized by a preglabellar area that is relatively short (sag.) compared with most species in the genus, but is close to those of *Birmanites latus* (Angelin 1851, p. 14, pl. 10; Kielan 1960, p. 78, pl. 6, figs. 1 and 2; pl. 7, fig. 3; pl. 8, fig. 4) from the Red Tretaspis Mudstones (Ashgill) of Västergötland, Sweden and *B. asiaticus* (Petrunina in Repina *et al.* 1975, p. 186, pl. 32, figs. 1–9) from the *Kielanella-Tretaspis* Beds (Ashgill) of southern Tian-Shan. The pygidium of *B. latus* is much shorter (sag.) than in the present form; that of *B. asiaticus* is comparable but slightly longer and has seven instead of five pairs of pleural ribs.

Birmanites sp. indet.

Plate 59, figs. 9 and 12

Figured specimens. One hypostoma (NI 80613) and one pygidium (NI 80614) from Bed 4.

EXPLANATION OF PLATE 59

Figs. 1, 4. *Telephina convexa* Lu, 1975. Bed 12. Cranium, dorsal and anterior views, NI 80604, $\times 4$.

Figs. 2, 5. *Telephina* sp. Bed 4. Cranium, dorsal and anterior views, NI 80605, $\times 4$.

Figs. 3, 6. *Nileus huanxianensis* Zhou in Zhou *et al.* 1982. Bed 12. Right librigena and attached cephalic doublure, NI 80606, $\times 2$.

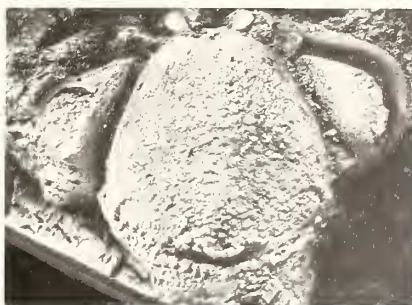
Figs. 7, 10, 11, 13–15. *Birmanites* aff. *asiaticus* (Petrunina in Repina *et al.* 1975). Bed 12. 7, cranium, NI 80607, $\times 1.5$. 10, pygidium, NI 80608, $\times 2$. 11, pygidium, NI 80609, $\times 4$. 13, pygidium, NI 80610, $\times 1$. 14 and 15, cranium, dorsal and left lateral views, NI 80611, $\times 2$.

Fig. 8. *Glaphurina* sp. Bed 4. Cranium, NI 80612, $\times 8$.

Figs. 9, 12. *Birmanites* sp. indet. Bed 4. 9, hypostoma, NI 80613, $\times 5$. 12, pygidium, NI 80614, $\times 4$.



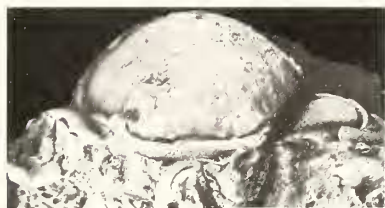
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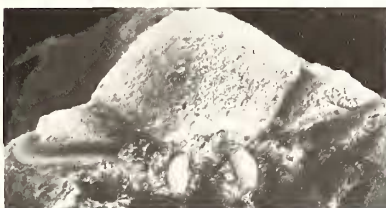
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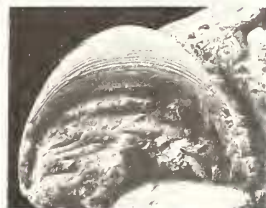
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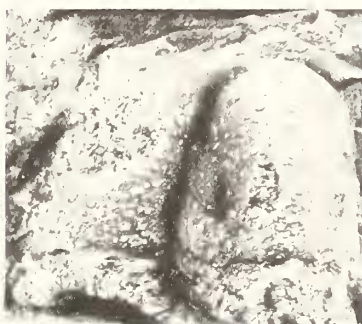
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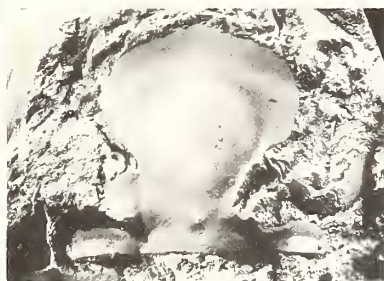
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13



14



15

Remarks. The well-preserved hypostoma has the middle body poorly defined, with middle furrow deeply incised abaxially; the posterior margin is forked, and the whole surface is covered with densely arranged, transverse terrace lines. The pygidium has a narrow, convex axis and slightly depressed border; it is semicircular in outline with nine pairs of pleural ribs. The only comparable described species is *B. yangtzeensis* Lu (1975, p. 321, pl. 8, figs. 9–13; pl. 9, figs. 1–5) from the Miaopo Formation (Llandeilo) of western Hubei, China, which has a relatively broader pygidial border and only six pairs of pleural ribs.

Family NILEIDAE Angelin, 1854

Genus NILEUS Dalman, 1827

Type species. *Nileus armadillo* Dalman, 1827, probably from the *Expansus* Limestone (Arenig; see Tjernvik 1956, p. 208) of Husbyfjöl, Östergötland, Sweden.

Nileus huanxianensis Zhou in Zhou *et al.* 1982

Plate 59, figs. 3 and 6; Plate 60, figs. 1–6, 8, 11

1982 *Nileus huanxianensis* Zhou in Zhou *et al.*, p. 266, pl. 66, fig. 9.

Diagnosis. Species of *Nileus* with cranium as long as wide, rounded anteriorly. Median glabellar tubercle placed anterior to line between posterior ends of palpebral lobes. Pygidium with shallow, broad border furrow. Surface of cranium smooth; pygidium covered with densely arranged fine ridges subparallel to margin.

Holotype. XI Tr-139, cranium, figured Zhou (in Zhou *et al.* 1982, pl. 66, fig. 9) from Bed 12 of the Chedao Formation, Chedao, Huanxian County, Gansu Province, China.

Figured specimens. Two cranidia (NI 80615, 80622), two hypostomata (NI 80618, 80619), one right librigena with cephalic doublure attached (NI 80606), one thoracic segment (NI 80621), two pygidia (NI 80616, 80620) and one pygidial doublure (NI 80617) from Bed 12.

Description. Cranium of low convexity, as long as wide, broadly rounded anteriorly. Median glabellar tubercle situated in front of line joining posterior ends of palpebral lobes. Weak medial glabellar ridge visible only on internal mould. Palpebral lobes semielliptical with length about two-fifths that of cranium, their posterior ends located one-sixth cranial length from posterior margin of cranium; palpebral furrows faint. Axial furrows weak. Anterior branches of facial suture diverge forwards at 60° to 90°; posterior branches diverge strongly backwards. Posterior areas of fixigenae very small, triangular, abaxially declined. Librigenae narrow (tr.) with no visible border; genal fields gently convex transversely; genal angles obtusely rounded; eye socles narrow, separated from genal fields by deep, broad furrows; eyes large, crescentic. Doublure widest (sag.) frontally, where it equals about one-third cephalic length, narrows sharply abaxially and is gently convex, upturned anteriorly and posterolaterally beneath the librigenae. Posteromedial part of doublure is depressed to form transverse groove immediately in front of transversely straight hypostomal suture. Rostral plate weakly defined by non-functional connective suture; outline trapezoidal, widest (tr.) frontally, where equals about two-fifths of cephalic width.

Hypostoma four-fifths as long as wide, flat, or weakly convex. Middle body ill defined, wider than long, with pair of depressed, elongate maculae sited on lateral margins opposite centre of hypostoma. Anterior wings small, triangular. Border gently convex, narrows anteriorly and posteriorly, and is tripartite posteriorly; posterior margin with pointed, broadly triangular median process; lateral and posterior borders well defined by deep, wide furrows and have low peripheral rim.

Thoracic segment (Pl. 60, fig. 8) with large articulating half ring well defined by deep, broad, transverse articulating furrow. Axial ring convex, with breadth (tr.) three-quarters that of segment overall. Axial furrows faint. Pleurae narrow (tr.) with rounded tips; triangular facets well developed outside fulcra that are sited close to axial furrows.

Moderately convex, unsegmented pygidium is subsemicircular in outline, length three-fifths the breadth. Large triangular axis occupies three-fifths anterior width and more than three-fifths length of pygidium, and is weakly defined by very shallow, broad axial furrows. Pleural lobes decline gently towards wide, shallow border

furrow; border indistinct, narrow (sag.), slightly convex. Doublure broad, deeply indented around tip of axis, and inner margin on either side is broadly curved, convex forwards.

Surface of cranidium, librigenae and thoracic axial rings smooth. Doublure, hypostoma, and thoracic pleurae covered with terrace lines. Dorsal surface of pygidium has densely crowded, fine ridges subparallel to margins; ridges are slightly thicker at anterolateral corners of pygidium.

Remarks. *Nileus huanxianensis* differs from *N. exarmatus obsoletus* Chang and Fan (1960, p. 110, pl. 12, figs. 13 and 14; pl. 3, figs. 1 and 2; text-fig. 11) from the Llanvirn of Qaidam, Qinghai Province, China in having a longer cranidium with anterior margin more strongly convex forwards, and smaller palpebral lobes. The pygidium of the Qinghai form is twice as broad as long with coarser but scattered transverse ridges on the surface. The Arenig subspecies *N. glazialis costatus* Fortey (1975a, p. 41, pl. 10; pl. 16, fig. 8) from Spitsbergen agrees in many respects with the present species, but differences shown by the former include: the slightly shorter (sag.) cranidium, steeply declined anteriorly; the less divergent posterior branches of the facial suture; the narrower (sag.) cephalic doublure; and the absence of a pygidial border. Both forms have quite different surface sculpture; the cranidium of *N. glazialis costatus* is finely punctate and the pleural lobes of the pygidium are covered with distinctive, deep grooves, only a few of which extend across the axis.

The Kazakhstan species *N. tengriensis* Weber (1948, p. 48, pl. 8, figs. 1–3, 5 and 6), from the Karakan horizon (Llandeilo), resembles *N. huanxianensis* in the outline of the pygidium and the size of its axis; but the cranidium has the median tubercle sited further back, and other cranidial features are comparable with those of *N. exarmatus obsoletus*.

Genus PERASPIS Whittington, 1965

Type species. *Niobe lineolata* Raymond, 1925, from the middle Table Head Formation (Llanvirn), Aguathuna, Port au Port Peninsula, southwestern Newfoundland.

Peraspis obscura sp. nov.

Plate 60, figs. 7, 9, 10, 12–15; Plate 61, fig. 1

Derivation of name. Latin *obscurus*, *a, um*, obscure, referring to the indistinct pygidial border furrow.

Holotype. Cranidium, NI 80628 (Pl. 60, fig. 13), from Bed 4.

Paratypes. Two cranidia (NI 80630, 80631a), four pygidia (NI 80623, 80624, 80625, 80629) and two hypostomata (NI 80626, 80627) from Bed 4.

Diagnosis. Species of *Peraspis* with wide pygidial axis that occupies less than two-fifths the pygidial width anteriorly. Pygidial border poorly defined. Cranidium without anterior border. Axial furrows straight and parallel opposite palpebral lobes. Hypostoma transverse with well-defined middle body and wide (tr.) lateral border.

Description. Cranidium of low convexity, as long as wide or slightly wider than long, rounded anteriorly. Gently convex glabella widest across anterolateral angles, highest along sagittal line but not carinate; tiny median tubercle sited behind transverse line between posterior ends of palpebral lobes. Axial furrows shallow on external surface, deep on internal moulds, parallel and straight between palpebral lobes, obscure between posterior ends of palpebral lobes and posterior cranidial margin, where they end at a pair of pits. Palpebral lobes long (0.4–0.45 cranidial length), semicircular in outline, narrow (tr.), faintly defined by weak palpebral furrows in testaceous specimens; transverse line joining posterior ends cuts sagittal line at about one-fifth of cranidial length from posterior cranidial margin. Palpebral areas of fixigenae slightly convex with width half length of palpebral lobes; posterior areas small, triangular, wider than long (exsag.). Anterior branches of facial suture diverge forwards at 90° to 120°; posterior branches diverge strongly backwards.

Hypostoma transversely elliptical in outline, four-fifths as long as wide, broadly rounded anteriorly. Middle body convex, oval, longer than wide, well defined by deep, wide lateral furrows; pair of deep middle furrows curve gently backwards from lateral margins of middle body at points one-third its length from rear. Anterior wings small, triangular. Lateral borders gently convex, their width two-fifths that of middle body, narrowing forwards to end near posterior corners of anterior wings; margins rounded. Posterior border narrow (sag.).

about half width (tr.) of lateral border; posterior margin tripartite with obtusely triangular median point. More or less uniformly narrow rim runs around lateral and posterior borders. Surface covered with coarse, transverse terrace lines.

Pygidium weakly vaulted, subsemicircular in plan with length about 0.7 the width. Convex, funnel-shaped axis occupies less than two-fifths anterior width and less than two-thirds length of pygidium; ring furrows almost obsolete. Axial furrows broad, entire. Pleural lobes unfurrowed; facets subtriangular, their width (tr.) two-thirds the anterior width of each pleural lobe. Border indistinct. Surface shows a few raised lines at anterolateral angles and near lateral and posterior margins. Doublure narrow (sag.), about one-third pygidial length at sagittal line; inner margin parallel to that of pygidium. Plate 60, fig. 14 shows an exfoliated transitory pygidium of *Peraspis obscura*.

Remarks. The hypostoma of the new species is of typical *Nileus* type, as in *N. armadillo* (Dalman 1827) (see Poulsen in Moore 1959, fig. 267, 1a), *N. limbatus* Brögger, 1882 (see Tjernvik, 1956, pl. 2, fig. 12), *N. exarmatus* Tjernvik (1956, pl. 2, fig. 16) and *N. platys stigmatus* Schrank (1972, pl. 8, fig. 5). However, its glabella is longer than in *Nileus* and the median glabellar tubercle is sited further back; the pygidium has a narrow (tr.), funnel-shaped axis and narrower (sag.) doublure with inner margin parallel to that of the pygidium. These features are found in *Peraspis* (Fortey 1975a, pp. 34, 35), to which genus we prefer to assign the species.

Compared with *Peraspis lineolata* (Raymond 1925) (see Whittington 1965, p. 364, pls. 34; 35; 36, figs. 11 and 12) the present species differs in: absence of anterior cranidial border; narrower (tr.) posterior areas of fixigenae; slightly wider glabella with median tubercle sited further forwards; straight instead of sinuous axial furrows; effaced pygidium with stouter axis; much more faintly defined pygidial border; and much better-defined middle body of hypostoma. *P. omega* Fortey (1975a, p. 49, pl. 20, figs. 1–11), from the late Arenig to Llanvirn of Spitzbergen, is also comparable with the new species in outline and size of cranidium and glabella. On the other hand the hypostoma and pygidium of *P. omega* are more similar to those of the type species, and its median glabellar tubercle and palpebral lobes are sited further forwards, so that the posterior areas of the fixigenae are longer (exsag.).

Family CYCLOPYGIDAE Raymond, 1925
Genus CYCLOPYGE Hawle and Corda, 1847

Type species. *Egle rediviva* Barrande, 1846, from the Černin Beds (Caradoc) of Trubin, near Beroun, Czechoslovakia.

Cyclopyge cf. *recurva* Lu in Wang *et al.*, 1962

Plate 61, figs. 2–5, 7–9, 14

Figured specimens. Three cranidia (NI 80632, 80633, 80634), one rostral plate with attached librigenae (NI 80635), and one pygidium (NI 80636), all from Bed 12.

Description. Glabella strongly convex (tr.), parabolic in outline, gently tapered forwards, strongly curved down anteriorly and overhangs preglabellar furrow. 1p glabellar furrows shallow, except for deep, pit-like middle portion, directed inwards and backwards, situated one-third of glabellar length from posterior margin;

EXPLANATION OF PLATE 60

Figs. 1–6, 8, 11. *Nileus huanxianensis* Zhou in Zhou *et al.* 1982. Bed 12. 1, cranidium, NI 80615, $\times 3$. 2, pygidium, NI 80616, $\times 3$. 3, pygidial doublure, NI 80617, $\times 3$. 4, hypostoma, NI 80618, $\times 5$. 5, hypostoma, NI 80619, $\times 6$. 6, pygidium, NI 80620, $\times 5$. 8, thoracic segment, NI 80621, $\times 3$. 11, cranidium, NI 80622, $\times 2$.

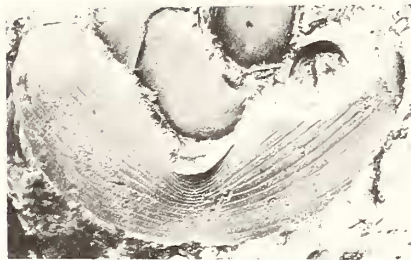
Figs. 7, 9, 10, 12–15. *Peraspis obscura* sp. nov. Bed 4. 7, transitory pygidium (Degree 6), paratype, NI 80623, $\times 6$. 9, transitory pygidium (Degree 6), paratype, NI 80624, $\times 6$. 10, pygidium, paratype, NI 80625, $\times 4$. 12, two hypostomata, paratypes, NI 80626 (above), 80627, $\times 8$. 13, cranidium, holotype, NI 80628, $\times 8$. 14, transitory pygidium (Degree 4), paratype, NI 80629, $\times 8$. 15, cranidium, paratype, NI 80630, $\times 8$.



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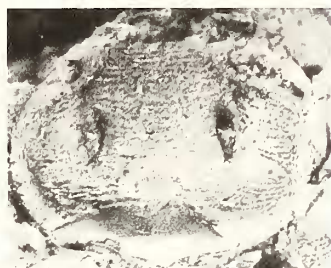
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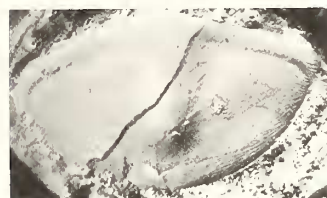
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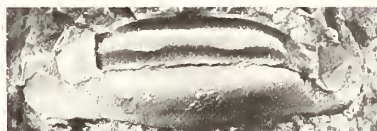
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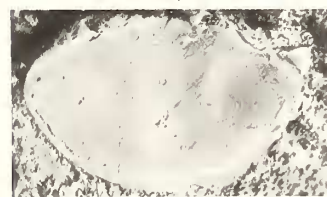
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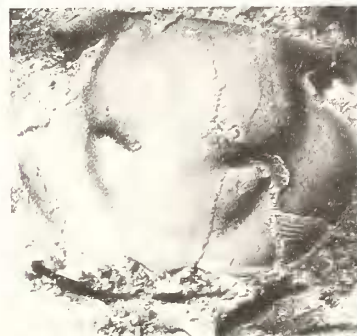
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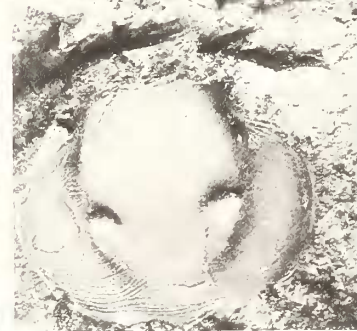
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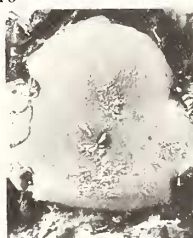
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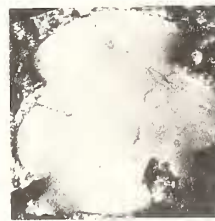
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circular swellings located between deep, pit-like part of 1p furrows and posterior end of cranidium; median glabellar tubercle in-line with distal ends of 1p furrows. Palpebral lobes narrow, band-like, well defined by deeply incised axial furrows, and meet in front of glabella at about 120°. Eyes separated by longitudinal groove that narrows upwards and alongside which there are only four eye facets for each eye. Rostral plate triangular in outline, one fourth as long as wide, with posterior margin slightly convex backwards and posterolateral angles produced to form narrow band that extends along ventral margin of eyes; median furrow broad, triangular, narrows forwards where confluent with groove between eyes; surface covered with transverse raised lines.

Pygidium subsemicircular in plan, its dorsal surface declined posteriorly. Axis strongly convex, slightly tapered backwards, broadly rounded posteriorly, and occupies about one-third anterior width and half overall length of pygidium; two axial rings and terminal piece are indicated by ornamentation of transverse raised lines, and narrow (sag.) articulating half-ring is raised and gently arched forwards. Axial furrows deep, wide. Postaxial field crossed by sagittal groove that reaches border furrow. Weakly convex pleural lobes carry pair of articulating facets and seven pairs transverse, raised lines on surface; anterior four pairs extend inwards from lateral margins to cross axis and meet, while three posterior pairs become faint towards axis. Border flat with width (sag.) about one-fifth pygidial length, narrows anteriorly and is covered with a few additional raised lines between the pairs of transverse lines noted above.

Remarks. The holotype of *C. recurva* Lu (1975, p. 377, pl. 30, figs. 8–12), from the Pagoda Formation (Caradoc) of southern Shaanxi, is poorly preserved but indistinguishable from the cranidia in our collection. However, librigenae of *C. recurva* are unknown and only transitory pygidia have been found. Recently published species of *Cyclopyge* from the Caradoc to Ashgill of north-west China and central and southern Tian-Shan have cranidia similar to that of *C. recurva* but different pygidia. They include: *C. beishanensis* Zhou (in Zhou *et al.* 1982, p. 268, pl. 67, figs. 5 and 6); *C. oculus* Abdullaev (1970, see Petrunina in Repina *et al.* 1975, p. 189, pl. 33, figs. 1–9, 11, 12, 14, 18); *C. abdullaevi* Petrunina (in Repina *et al.* 1975, p. 187, pl. 31, figs. 11–14, 16, 23); and *C. binodosa* Zhang (1981, p. 191, pl. 72, figs. 1–3). Of these *C. binodosa* Zhang (not to be confused with *Aeglina binodosa* Salter, 1859, later placed in *Cyclopyge* and finally made type species of *Priscyclopyge* R. and E. Richter, 1954) is very similar to the present form and may be conspecific with it, but the evidence is as yet insufficient.

The pygidium of *C. cf. recurva* resembles that of *C. vigilans* (Cooper and Kindle 1936, p. 367, pl. 52, figs. 36, 39, 41–51), from the Ashgill of eastern Canada, in the outline, wide border, and presence of a postaxial depression; the only difference is the bluntly pointed posterior margin of *C. vigilans*. The glabella of *C. cf. recurva* is narrower than that of *C. vigilans* but comparable with that of *C. mirabilis* (Forbes MS in Salter, 1853) (assigned to *Phylacops* by Whittard 1952, pl. 32, figs. 6–8) from the Portraine Limestone (Ashgill) of eastern Ireland; the last-named has the glabellar furrows deeply incised throughout their length and its eyes are much broader mesially in anterior view.

Genus MICROPARIA Hawle and Corda, 1847

Type species. *Microparia speciosa* Hawle and Corda, 1847, from the Králův Dvůr Beds (Ashgill) of Králův Dvůr, Czechoslovakia.

Subgenus QUADRAPYGE Zhou in Zhou *et al.*, 1977

Type species. *Microparia (Quadrpyge) latilimbata* Zhou in Zhou *et al.*, 1977, from the Modaoxi Formation (Caradoc) of Modaoxi, Taojiang County, Hunan Province, China.

Diagnosis. Dorsal shield elliptical in plan. Glabella parabolic in outline without glabellar furrows; median tubercle present. Eyes long, separated by frontal glabellar tongue. Thorax of five segments. Pygidium rectangular, well segmented on exfoliated surface; axis entire, rounded posteriorly; well developed border narrows anteriorly; border furrow deep, broad.

Remarks. This diagnosis is based on both the type species *M. (Q.) latilimbata* Zhou (in Zhou *et al.* 1977, p. 230, pl. 69, figs. 14–16) and *M. (Q.) chedaoensis* sp. nov. described below. The cephalic characters agree well with those of *Microparia* (*Microparia*) but the pygidium of the latter is

semicircular in outline; the axis is triangular and faintly defined; the pleural lobes are almost unfurrowed; and the border furrow is shallower.

Microparia (Quadrapyge) chedaoensis sp. nov.

Plate 61, figs. 6, 10, 11, 13, 16

Name. After Chedao, a small town near the measured section.

Holotype. Pygidium, NI 80640 (Pl. 61, fig. 16), from Bed 4.

Paratypes. Two pygidia (NI 80631b, 80639) and two cranidia (NI 80637, 80638), all from Bed 4.

Diagnosis. *Microparia (Quadrapyge)* species with median tubercle situated in centre of glabella when viewed dorsally. Pygidial axis narrow (tr.); width (sag.) of border about one-fifth sagittal length of pygidium.

Description. Cranidium longer than wide. Glabella parabolic in outline, slightly tapered forwards, strongly curved down anteriorly, and fused posteriorly with occipital ring; median tubercle located in centre of glabella when viewed dorsally; anterior tongue short (sag.), curved down frontally where extends further forwards than anterior ends of palpebral lobes; glabellar furrows absent. Axial furrows deep beside palpebral lobes, shallow and curve inwards from posterior ends of palpebral lobes to posterior margin of glabella. Palpebral lobes ridge-like and narrow slightly forwards. Anterior branches of facial suture converge gently forwards; posterior branches diverge slightly backwards. Rostral suture short (tr.), transversely straight. Posterior areas of fixigenae small, triangular, low, and decline abaxially.

Pygidium rectangular in outline, its length two-thirds the width. Axis tapers backwards and is broadly rounded posteriorly; it occupies half length (sag.) and more than one-third anterior width of pygidium and is faintly defined by shallow axial furrows. In testaceous specimens axis includes a ridge-like articulating half-ring, well-defined first axial ring, and large terminal piece; pleural lobes decline slightly towards border furrow and are unfurrowed except for first pair pleural furrows, which demarcate convex, narrow (exsag.) pair anterior half ribs. In internal moulds the axis is well defined, with five rings and small terminal piece, and the pleural lobes exhibit six broadly furrowed pleurae. Border low, flat, with posterior margin slightly bent down and bluntly pointed; width (sag.) about one-fifth pygidial length at sagittal line but quickly narrows (tr.) forwards; inner margin semi-circular, well defined by deep, broad border furrow.

Surface of cranidium covered with widely spaced raised lines near and subparallel to anterior and posterior margins. Pygidium has transverse raised lines on posterior border and postaxial part of pleural fields. Pleural lobes have paired raised lines running parallel to pleural furrows; some raised lines join across axis, and most reach lateral margins of pygidium. Doublure ornamented with terrace lines.

Remarks. The new species resembles *M. (Q.) latilimbata* in many respects, but the latter differs in its wider (tr.) pygidial axis (anterior width two-fifths to one-half that of pygidium) and wider border (about one-third length of pygidium at sagittal line). Known cephalae of the type species are flattened and precise comparison is difficult, but the glabella seems much wider than in the new species and the median tubercle is located in front of centre of the glabella.

Family STYGINIDAE Vogdes, 1890

Genus PSEUDOSTYGINA Zhou in Zhou *et al.*, 1982

Type species. *Pseudostygina lepida* Zhou in Zhou *et al.*, 1982, from the upper part of the Chedao Formation (Caradoc) of Chedao, Huanxian County, Gansu Province, China.

Diagnosis. Styginid trilobites with well-defined, convex anterior and lateral cephalic borders. Glabellar and occipital furrows absent. Genal angles rounded. Hypostoma with strongly convex, divided middle body, its oval outline strongly convex forwards; anterior wings large, subquadrate; lateral and posterior borders convex. Pygidial axis short (sag.), parallel-sided, rounded posteriorly; pleural lobes unfurrowed; border faintly defined.

Remarks. The narrow (tr.) cranidium, with well-defined glabella that expands steadily forwards, suggests that the genus is a typical styginid. *Pseudostygina* differs from *Stygina* Salter, 1853 in its

lack of an occipital furrow, the rounded genal angles, the shorter (sag.) pygidial axis, the absence of first pygidial pleural furrows, and the more weakly defined pygidial border. The preglabellar furrow is obscure in the lectotype of the type species of *Stygina*, *S. latifrons* (Portlock 1843) (see Whittington 1950, pl. 172, figs. 1–3) and only faint in certain other specimens (Whittington 1950, pl. 72, figs. 4 and 5; Skjeseth 1955, pl. 1, figs. 3–5, 7 and 8). The anterior pits in the axial furrows of *Stygina*, emphasised by Skjeseth, are lacking in *Pseudostygina*; in addition the cephalic border of *Stygina* is flat or upturned. *Raymondaspis* Přibyl, 1948 has a well-defined anterior border as in *Pseudostygina*, and the shape and size of cranium and glabella in both genera are comparable. *Raymondaspis* is distinguished by the wider (tr.) pygidium with longer (sag.), triangular axis, the presence of librigenal spines, and the prominent occipital furrow, pygidial border furrow and first pygidial pleural furrows.

The hypostoma of *Pseudostygina* is similar in shape to that of other styginids but is characterized by the convex lateral and posterior borders, the better-defined middle body with maculae on its lateral margins, and the anterior margin, which is more strongly convex forwards medially. These features are also typical of the hypostoma in scutelluids, but in its large, subquadrate anterior wings and elongate, oval middle body the hypostoma of *Pseudostygina* differs from that of scutelluids but resembles that of illaenids. On the other hand a pair of anterior pits on the cranium, which is characteristic of styginids (Lane and Thomas 1983), is not found in *Pseudostygina*, and this may suggest a further similarity to the illaenids. In the general features of its cephalon and pygidium *Pseudostygina* also resembles illaenid species such as *Illaenus spitiensis* Reed, 1912, but the type species, *P. lepida*, has the glabella well defined laterally as well as frontally, a prominent anterior border, and a parallel-sided pygidial axis with rounded tip. On the whole *Pseudostygina* is a typical styginid but shares some important characters with illaenids, a conclusion that favours a close relationship between styginids and illaenids, as recently discussed by Lane and Thomas (1983).

Pseudostygina lepida Zhou in Zhou *et al.*, 1982

Plate 61, figs. 12, 15, 17–20; Plate 62, figs. 1–5

1982 *Pseudostygina lepida* Zhou in Zhou *et al.*, p. 273, pl. 68, figs. 5 and 6.

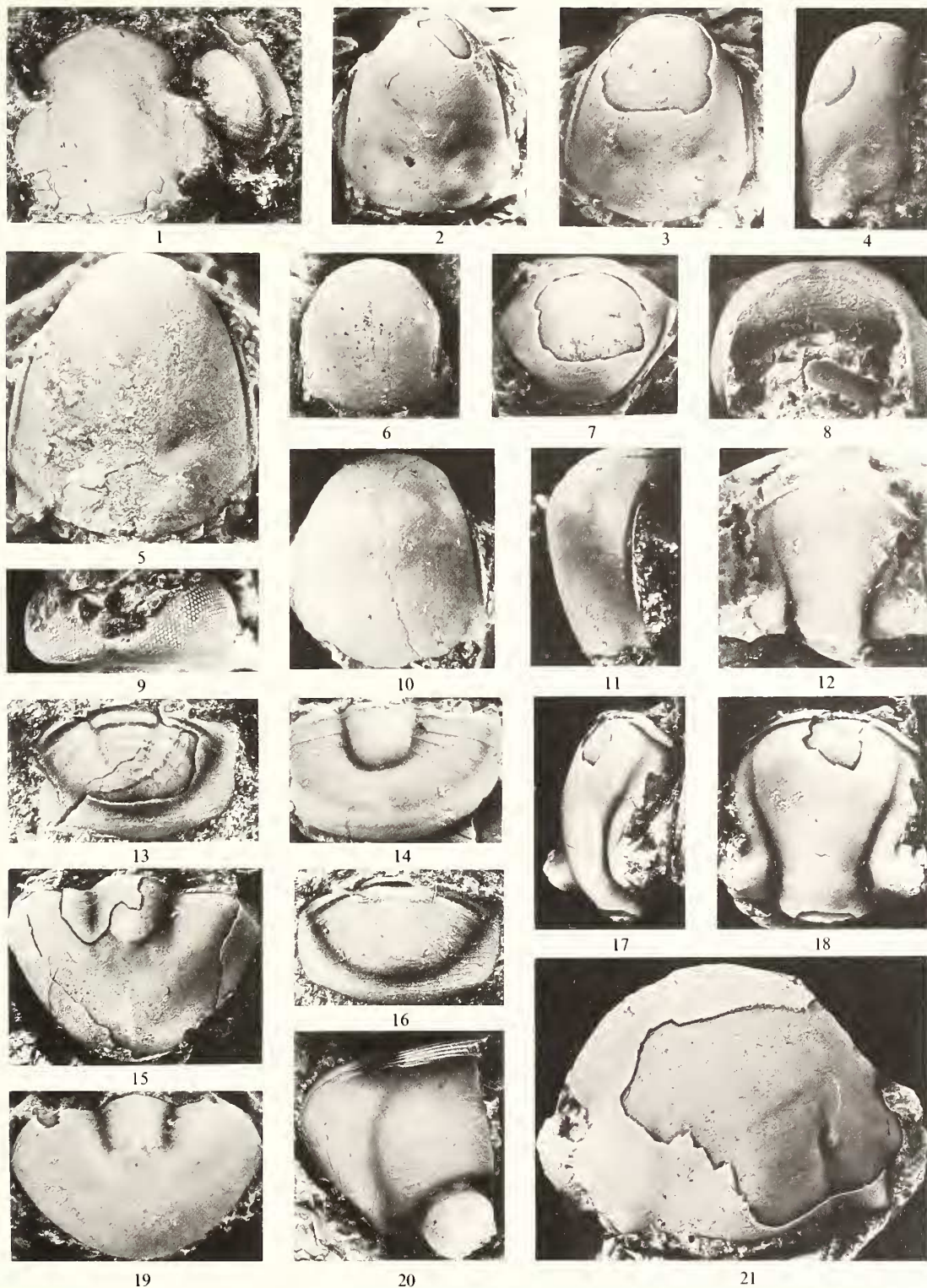
Diagnosis. As for genus.

Holotype. Cranium (XI Tr159), figured Zhou (in Zhou *et al.* 1982, pl. 68, figs. 5a, b), from Bed 12 of the Chedao Formation, Chedao, Huanxian County, Gansu Province, China.

Figured specimens. Three cranidia (NI 80641, 80643, 80647), two hypostomata (NI 80648, 80650), one left librigena (NI 80645) and three pygidia (NI 80642, 80644, 80649), all from Bed 12.

EXPLANATION OF PLATE 61

- Fig. 1. *Peraspis obscura* sp. nov. Bed 4. Paratype cranium, NI 80631a, with associated paratype pygidium, NI 80631b, of *Microparia (Quadrapyge) chedaoensis* sp. nov., $\times 6$.
 Figs. 2–5, 7–9, 14. *Cyclopyge* cf. *recurva* Lu, 1962. Bed 12. 2, cranium, NI 80632, $\times 5$. 3, 4, 7, cranium, dorsal, right lateral and anterior views, NI 80633, $\times 6$. 5, cranium, NI 80634, $\times 8$. 8, 9, rostral plate with eyes attached, ventral and anterior views, NI 80635, $\times 5$. 14, pygidium, NI 80636, $\times 8$.
 Figs. 6, 10, 11, 13, 16. *Microparia (Quadrapyge) chedaoensis* sp. nov. Bed 4. 6, cranium, paratype, NI 80637, $\times 6$. 10, 11, cranium, dorsal and right lateral views, paratype, NI 80638, $\times 10$. 13, pygidium, paratype, NI 80639, $\times 10$. 16, pygidium, holotype, NI 80640, $\times 10$.
 Figs. 12, 15, 17–20. *Pseudostygina lepida* Zhou in Zhou *et al.* 1982. Bed 12. 12, small cranium, NI 80641, $\times 6$. 15, pygidium, NI 80642, $\times 3$. 17, 18, cranium, right lateral and dorsal views, NI 80643, $\times 3$. 19, small pygidium, NI 80644, $\times 8$. 20, left librigena, NI 80645, $\times 5$.
 Fig. 21. *Stenopareia* aff. *bowmami* (Salter, 1848). Bed 12. Cranium NI 80646, $\times 4$.



Description. Cranium broadly rounded frontally, rounded anterolaterally, gently convex in lateral view, longer than wide, widest across base. Glabella moderately convex, expands forwards from opposite palpebral lobes, where its width (tr.) is about three-fifths the maximum, attained near anterior margin; its outline is broadly rounded anteriorly, rounded anterolaterally, and there are no glabellar furrows. An oval anterior muscle scar on the exfoliated surface of a cranium (Pl. 62, fig. 1) and a pair of smooth patches on the glabellar flanks opposite the palpebral lobes of a well-preserved specimen (Pl. 61, fig. 12) provide evidence of two subparallel rows muscle scars. Occipital furrow absent. Axial furrows wide, deep posteriorly but gradually shallow and narrow forwards. Palpebral lobes small, semicircular, length about one-sixth that of cranium, strongly convex, standing high above fixigenae and glabella and situated well back. Anterior branches of facial suture long, gently divergent, running forwards in abaxially convex curves; very short posterior branches extend abaxially backwards. Preglabellar field absent. Anterior border narrow, ridge-like, uniform in width (sag.), well defined by distinct anterior border furrow. Fixigenae narrow (tr.); low, narrow (exsag.), triangular posterior areas include pair subcircular alae located adjacent to axial furrows. Librigenae with rounded genal angles; genal fields broad, subquadrate, vaulted; eye socles narrow, vertical, bounded by deep, broad furrows; reniform eyes stand high above genal fields, and visual surface is crowded with very small facets. Lateral border narrow, upturned; posterior border weakly convex, markedly wider (exsag.) abaxially; border furrows broad. Cephalic doublure steeply declined, densely covered with terrace lines.

Hypostoma shield-shaped, arched forwards medially, rounded posteriorly. Anterior wings large, subquadrate. Middle body four-fifths as long as wide, oval, well defined by deep, broad border furrows; it is divided into a large, strongly convex anterior lobe, length (sag.) three-quarters that of middle body, and a small, weakly convex posterior lobe; transverse median furrow is deep and wide laterally, shallow mesially, and slightly curved forwards; transversely oval maculae prominent, sited at anterolateral corners of posterior lobe. Anterior border narrow (sag.), flat; lateral borders subparallel anteriorly, converge opposite median furrow, and then confluent with wide (sag.), strongly convex posterior border.

Large pygidium semielliptical in outline, with length three-quarters width; small specimen sub-semicircular (Pl. 61, fig. 19), three-fifths as long as wide; anterolateral facets triangular, their width (tr.) one-eighth that of pygidium. Short (sag.) parallel-sided axis occupies one-third length and slightly more than one-quarter width of pygidium; it is rounded posteriorly and unfurrowed except for faint first ring furrow on external surface. Axial furrows deep, broad, but shallow posteriorly, and there is a post-axial ridge. A pair of oval muscle scars close to posterior part of axial furrows is visible, particularly on exfoliated surfaces. Pleural lobes unfurrowed, their dorsal surface declined both abaxially and towards anterior part axial furrows; border furrow indistinct. Doublure with evenly curved inner margin, narrowing (tr.) forwards; width (sag.) at sagittal line less than one-third pygidial length.

Surface of cranium covered with densely grouped transverse raised lines in small specimen (Pl. 61, fig. 12); large specimens have only a few similar raised lines on anterior part of glabella and on palpebral areas of fixigenae. Genal fields of librigenae have anastomosing ridges subparallel to lateral margins; posterior border ornamented with scattered anastomosing ridges subparallel to posterior border furrow. Hypostoma has coarse ridges, subparallel to lateral and posterior margins, on anterior lobe of middle body, and on lateral and posterior borders. In most examples of the pygidium, the frontal portion carries three pairs widely spaced, transverse ridges, subparallel to anterior margin.

EXPLANATION OF PLATE 62

- Figs. 1–5. *Pseudostygina lepida* Zhou in Zhou *et al.* 1982. Bed 12. 1, cranium, NI 80647, $\times 4$. 2, hypostoma, NI 80648, $\times 6$. 3, 4, pygidium, dorsal and left lateral views, NI 80649, $\times 4$. 5, hypostoma, NI 80650, $\times 8$.
 Figs. 6–11, 16. *Stenopareia* aff. *bowmanni* (Salter, 1848). Bed 12. 6, pygidium, NI 80651, $\times 2$. 7, pygidium, NI 80652, $\times 1.5$. 8, 9, small cranium, dorsal and right lateral views, NI 80653, $\times 4$. 10, pygidium showing doublure, NI 80654, $\times 2$. 11, small cranium, NI 80655, $\times 4$. 16, transitory pygidium, NI 80656, $\times 12$.
 Fig. 12. *Stenopareia* sp. indet. Bed 4. Cranium, NI 80657, $\times 2$.
 Figs. 13–15. *Paraphillipsinella globosa* Lu in Lu & Chang 1974. Bed 12. 13, 14, cranium, dorsal and left lateral views, NI 80658, $\times 12$. 15, cranium, NI 80659, $\times 12$.
 Figs. 17 and 18. *Xenocybe*? sp. Bed 12. 17, cranium, NI 80660, $\times 10$. 18, pygidium, NI 80661, $\times 10$.
 Fig. 19. *Rorringtonia* sp. Bed 4. Cranium, NI 80662, $\times 10$.
 Fig. 20. *Ischyrophlyma*? *zhiqiangi* sp. nov. Bed 12. Cranium, paratype, NI 80663, $\times 10$.



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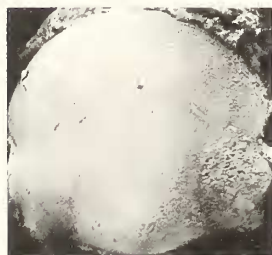
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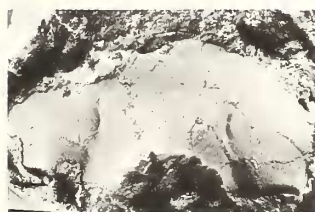
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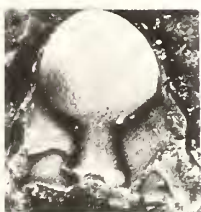
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Family ILLAENIDAE Hawle and Corda, 1847

Genus STENOPAREIA Holm, 1886

Type species. Illaenus linnaerossi Holm, 1882 from the Boda Limestone (Ashgill) of the Siljan district, Dalarne, Sweden.

Stenopareia aff. *bowmanni* (Salter, 1848)

Plate 61, fig. 21; Plate 62, figs. 6-11, 16

Figured specimens. Three cranidia (NI 80646, 80653, 80655) and four pygidia (NI 80651, 80652, 80654, 80656) from Bed 12.

Description. Cranidium wider than long, broadly and evenly rounded frontally in plan. Glabella slightly less convex posteriorly, its basal width twice that of each palpebral area. Broad, shallow axial furrows converge forwards until level with middle of palpebral lobes and then diverge slightly forwards, dying out in front of line joining mid-points of palpebral lobes. Palpebral lobes about one-sixth length of cranidium, gently convex abaxially, placed far back, so that the posterior end of each lobe is about half its own length from the posterior margin. Surface of internal mould shows pair of elliptical lunettes (Whittington 1954, p. 139) opposite palpebral lobes, small posteriorly situated median glabellar tubercle, weakly defined median glabellar ridge, four pairs faint muscle scars that decrease in size forwards, and broad (exsag.) posterior border furrow.

Pygidium semielliptical in outline, truncated anterolaterally by weakly defined facets. Axis occupies half anterior width of pygidium, but is otherwise poorly defined. Doublure U-shaped, narrow (tr.) anteriorly, wide (sag.) posteriorly where it occupies about half pygidial length; inner margin of the doublure gently convex forwards medially; its surface is ornamented with faint terrace lines. A small transitory pygidium (Pl. 62, fig. 16) is semicircular in outline, length less than three quarters its width, steeply curved down to the margins; the well defined axis occupies 0.4 width and 0.7 length of the pygidium. Surface of anterior third of largest cranidia carries terrace lines subparallel to anterior margin; similar lines occur in fixigenae of smallest cranidium (Pl. 62, fig. 8).

Remarks. As far as we are aware, only three other species of *Stenopareia* have a pygidial doublure similar to that of the present form. They are: *Stenopareia bowmanni* (Salter 1848) (see Whittard 1961, p. 217, pl. 31, figs. 1, 2; Price 1974, p. 842, pl. 112, figs. 1-8, ?) from the Ashgill of South Wales; *Stenopareia miaopoensis* Lu (1975, p. 387, pl. 32, fig. 13; pl. 33, figs. 1-3) from the lower Miaopo Formation (Llandeilo) of western Hubei, China; and *Stenopareia?* sp. of Dean (1978, pl. 50, figs. 4, 6, 8) from the Chair of Kildare Limestone (Ashgill) of eastern Ireland. In the two last species the inner margin of the doublure is much more convex forwards at and near the sagittal line than in *S. bowmanni* and the present Chinese form. In shape of cranidium and pygidium, and in size of glabella our material resembles *S. bowmanni* but differs in having larger palpebral lobes; the lectotype of *S. bowmanni* is somewhat crushed and further comparison is impracticable.

Stenopareia sp. indet.

Plate 62, fig. 12

Figured specimen. Cranidium NI 80657, from Bed 4.

Remarks. This poorly preserved specimen is inadequate for confident generic assignment, but the posteriorly situated small palpebral lobes suggest that it may best be assigned to *Stenopareia*.

Family PHILLIPSINELLIDAE Whittington, 1950

Genus PARAPHILLIPSINELLA Lu in Lu and Chang, 1974

Type species. Paraphillipsinella globosa Lu in Lu and Chang, 1974 from the Pagoda Formation (Caradoc), Chenkou, Sichuan Province, China.

Diagnosis. Phillipsinellid trilobites with glabella separated into a swollen, spherical frontal lobe and a cylindrical posterior lobe that tapers forwards slightly. Four pairs of pit-like lateral glabellar lobes on flanks of posterior glabellar lobe. Eyes small, almost spherical. Anterior border absent. Rostral

plate large, trapezoidal, wider than long, Pygidium faintly furrowed, without border or border furrow.

Remarks. The diagnosis is based on new material in addition to well-preserved specimens described by Ji (1982) and Ju (in Qiu *et al.* 1983).

The genus differs from *Phillipsinella* Novák, 1885 mainly in the more swollen frontal glabellar lobe, the lack of an anterior border, and the smaller, spherical eyes. *Protophillipsinella* Chen in Li *et al.* 1975 is indistinguishable from *Paraphillipsinella*, as noted by Xia (1978, p. 176), Lu and Zhou (1981, p. 14) and Ji (1982), and is considered a junior subjective synonym.

Species of *Paraphillipsinella* have been recorded from the Caradoc to early Ashgill of the Yangtze region by Lu (in Lu and Chang 1974), Chen (in Li *et al.* 1975, as *Protophillipsinella*), Zhou (in Zhou *et al.* 1977), Sheng (1974, as *Phillipsinella*), Xia (1978), Ji (1982) and Ju (in Qiu *et al.* 1983), but ranges of variation are not available for most of them because of limited material. Lu and Zhou (1981, p. 14) believed that *Paraphillipsinella* included only two species: *P. globosa*, with subcircular, and *P. nanjiangensis* Lu in Lu and Chang, 1974 with transversely oval frontal glabellar lobe.

Paraphillipsinella globosa Lu in Lu and Chang, 1974

Plate 62, figs. 13–15

1974 *Paraphillipsinella globosa* Lu in Lu and Chang, p. 133, pl. 53, figs. 8 and 9.

1974 *Phillipsinella* sp., Sheng, p. 77, pl. 2, figs. 14–16.

1975 *Protophillipsinella typa* Chen in Li *et al.*, p. 156, pl. 20, fig. 5a, b.

1975 *Protophillipsinella curvusa* Chen in Li *et al.*, p. 157, pl. 20, fig. 9a, b.

1977 *Paraphillipsinella hubeiensis* Zhou in Zhou *et al.*, p. 241, pl. 73, figs. 5 and 6.

1978 *Paraphillipsinella globosa* Lu; Xia, p. 175, pl. 34, figs. 9–11.

non 1983 *Paraphillipsinella hubeiensis* Zhou; Ju in Qiu *et al.*, p. 228, pl. 76, figs. 8 and 9 (= *Paraphillipsinella nanjiangensis* Lu in Lu and Chang, 1974)

Holotype. Cranidium, figured Lu (in Lu and Chang 1974, pl. 53, figs. 8 and 9), from the Pagoda Formation (Caradoc), Chenkou, Sichuan Province, China.

Figured specimens. Two cranidia (NI 80658, 80659) from Bed 12.

Description. Cranidium wider than long. Glabella divided into anterior and posterior lobes; anterior lobe subspherical, wider than long, three-fifths as long as cranidium and almost as wide as cranidium across base, strongly curved down anteriorly and laterally but only gently posteriorly; posterior lobe low, moderately tapered forwards, transversely convex with basal width about two-fifths that of frontal lobe. Four pairs faint, pit-like glabellar furrows situated on margins of flanks of glabella; 4p pair located between frontal and posterior lobes. Occipital ring higher than posterior lobe and slightly wider (tr.) than base of glabella; occipital furrow shallow. Axial furrows deep, broad. Fixigenae gently convex, declined laterally. Palpebral lobes small, sited opposite anterior part of posterior lobe of glabella. Posterior border flat, widens abaxially, separated from fixigena by shallow border furrow that is broader (exsag.) in exfoliated specimens. Anterior branches of facial suture at first subparallel, turn inwards anteriorly and extend along frontal margin of glabella; posterior branches short, slightly divergent backwards. Surface of exoskeleton densely pitted.

Remarks. The present specimens agree well with the holotype and those described as *Phillipsinella* sp. by Sheng (1974). The holotypes of *Protophillipsinella typa* Chen and *P. curvusa* Chen from the Pagoda Formation of southern Saanxi, and of *Paraphillipsinella hubeiensis* Zhou from the Linhsiang Formation of Xuan, western Hubei agree with *Paraphillipsinella globosa* in both morphological characters and ratio of length: width of the frontal glabellar lobe of the glabella to the posterior lobe. All three species were therefore considered synonymous by Ju (in Qiu *et al.* 1982, p. 59).

Specimens recorded as *P. hubeiensis* Zhou by Ju (in Qiu *et al.* 1982) from the Huangnekang Formation (early Ashgill) of western Zhejiang, eastern China, have the frontal glabellar lobe transversely oval in outline, a feature differing from the type species but comparable with *P. nanjiangensis* Lu (in Lu and Chang 1974, p. 133, pl. 53, fig. 10).

Family PROETIDAE Salter, 1864
 Subfamily PROETINAE Salter, 1864
 Genus XENOCYBE Owens, 1973

Type species. *Xenocybe micrommata* Owens, 1973, from the Tretaspis Series, Stage 5a (Ashgill), of Holmen-skjaeret, Oslo region, Norway.

Xenocybe? sp.

Plate 62, figs. 17 and 18

Figured specimens. Cranidium (NI 80660) and pygidium (NI 80661) from Bed 12.

Remarks. The cranidium, imperfectly preserved, has rounded, subtriangular, inflated glabella, narrow (sag.), depressed preglabellar field, and the strongly convex anterior border is semicircular in cross section. Position of posterior end of anterior branches of facial suture close to axial furrows suggests that palpebral area of fixigenae was very narrow. The specimen is generally comparable with the holotype of *Xenocybe micrommata* Owens (1973, fig. 14G) but differs in its shorter glabella and fainter 2p and 3p furrows, features that in turn resemble those of the holotype of the type species of *Panarchaeogonus*, *P. parvus* Öpik, 1937, refigured by Owens (1979, fig. 4 A-D). The pygidium is characterized by virtual lack of interpleural furrows and border furrow, but in its broad axis and transverse outline it is more like *Panarchaeogonus* (See Owens 1979, fig. 4N) than *Xenocybe* (see Lane and Owens 1982, pl. 3, figs. 1 and 2).

Trigonoproetus triquetrus Apollonov (1974, p. 38, pl. 19, figs. 1-3) from the Ashgill of Kazakhstan may be conspecific with the Chinese species but its pygidium is unknown. *Trigonoproetus* Apollonov, 1974 was considered synonymous with *Xenocybe* by Lane and Owens (1982).

Family AULACOPLEURIDAE Angelin, 1854
 Subfamily SCHARYIINAE Osmólska, 1957
 Genus RORRINGTONIA Whittard, 1966

Type species. *Rorringtonia flabelliformis* Whittard, 1966 from the Rorrington Beds, Shelve inlier, Shropshire, England. Although the Rorrington Beds extend from about middle Llandeilo to lowest Caradoc, Whittard's (1966, table 5) record of *R. flabelliformis* from only the lower half of the unit suggests that the species is of Llandeilo age in its type area.

Rorringtonia sp.

Plate 62, fig. 19

Figured specimen. Cranidium (NI 80662) from Bed 4.

Description. Cranidium gently convex, its outline slightly arched forwards frontally. Glabella subtriangular, length about two-thirds that of cranidium, broadly rounded anteriorly, as long as wide, slightly convex transversely and declined forwards; outline tapers forwards and its lateral margins are broadly curved, abaxially convex. Three pairs narrow, distinct, lateral glabellar furrows decrease in size posteriorly; 1p furrows curve adaxially, defining 1p lobes whose length is more than one third that of glabella; 2p furrows run parallel to abaxial part of 1p furrows and end opposite centre of glabella; 3p furrows run slightly forwards adaxially; suggestion of 4p furrow on left side of glabella may be result of crushing. Occipital ring narrows (exsag.) laterally; occipital furrow narrow (sag.), transversely straight medially, turns backwards distally. Axial furrows narrow, deep. Palpebral lobes reniform, slightly convex abaxially, sited close to glabella; their length is one-third that of glabella and they end posteriorly opposite abaxial ends of 1p furrows. Anterior branches of facial suture subparallel; posterior branches straight, running obliquely backwards and outwards. Preglabellar area wide (sag.), equal to one-quarter length of cranidium, slightly vaulted, with narrow (sag.), convex anterior border well defined by shallow border furrow. Posterior areas of fixigenae each have outline of right-angled triangle, with width one-quarter that of base of cranidium; narrow posterior border furrow separates posterior border that is narrow (exsag.) proximally and widens distally.

Remarks. Species of *Rorringtonia* have been reported from the Llandeilo and low Caradoc of Britain and Norway (Whittard 1966; Owens 1973; Hughes 1979; Owens 1981). Of all these species, the present form is closest to *R. kennedyi* Owens (1981, p. 91, pl. 1, figs. *a-d*), from the Llandeilo of Llandrindod Wells, central Wales, but differs in having a longer glabella and cranidium, and narrower glabellar furrows. *Madygenia snavis* Petrunina (in Repina *et al.* 1975, p. 230, pl. 45, figs. 6 and 7, 12–17), from southern Tyan-Shan, type species of *Madygenia*, generally resembles the present cranidium. Minor differences include the more strongly declined preglabellar area and more weakly defined anterior border of the Russian species. The diagnostic characters of *Madygenia* fall within the range of variation in *Rorringtonia* and the two are probably congeneric, though a decision must await further information on the thoracic and pygidial characters of *Madygenia*.

?Family DIMEROPYGIDAE Hupé, 1953
Genus ISCHYROPHYMA Whittington, 1963

Type species. *Ischyrophyma tuberculata* Whittington, 1963, from a white limestone boulder in a conglomerate (latest Arenig–basal Llanvirn) of the Cow Head Group, Lower Head, western Newfoundland, Canada.

Ischyrophyma? zhiqiangi sp. nov.

Plate 62, fig. 20; Plate 63, figs. 1–7, 12

Name. After Zhou Zhiqiang, of the Xian Institute of Geology and Mineral Resources, who did much to help the authors in this project.

Holotype. Cranidium, NI 80665 (Pl. 63, figs. 2, 7), from Bed 12.

Paratypes. Three cranidia (NI 80663, 80664, 80666) and four pygidia (NI 80667, 80668, 80669, 80670), all from Bed 12.

Diagnosis. A possible *Ischyrophyma* species with relatively large 1p glabellar lobes. Glabella constricted in front of anterior ends of 1p furrows. Pygidium semicircular in plan, with well-defined conical axis and broad border. Surface finely granulate.

Description. Glabella strongly convex transversely, steeply turned down frontally to overhang slightly the preglabellar furrow; glabella about as long as wide, subparallel-sided, broadly rounded anteriorly, its outline slightly constricted in front of anterior ends of 1p furrows. Two pairs distinct glabellar furrows present: 1p deep, broad, narrowing posteriorly, connected by shallow depressions to occipital furrow and axial furrows, and separating pair of subquadrate, inflated glabellar lobes that occupies more than one-quarter width and one-third to one-quarter length of glabella; 2p furrows short, directed slightly backwards adaxially, and show as smooth patches on external surface but as shallow depressions on internal mould, opposite anterior ends of palpebral lobes. Occipital ring uniformly wide (sag.) medially, where equals one-sixth glabellar length, but narrows (exsag.) sharply towards axial furrows from points opposite posterior end of 1p furrows; there is a prominent median tubercle, and posterior margin of cranidium curves gently forwards laterally. Occipital furrow deep, broad (exsag.), overhung laterally by 1p lobes. Axial furrows deeply incised. Preglabellar field absent at sagittal line. Anterior border upturned, low, almost uniformly narrow (sag.). Palpebral lobes semicircular in plan, small (about one-fifth length of cranidium), and end posteriorly opposite centre of cranidium and close to axial furrows. Anterior branches of facial suture diverge slightly forwards; posterior branches run backwards and slightly outwards. Posterior areas of fixigenae triangular, abaxially declined, their length and width nearly same as for 1p lobes. Posterior border low, narrow (exsag.).

Pygidium semicircular in plan, three-fifths as long as wide. Strongly convex, conical axis rounded posteriorly and occupies two-fifths frontal width of pygidium; it comprises a large articulating half-ring, five axial rings, and a terminal piece, all separated by curved ring furrows that shallow medially. Axial furrows deep, broad. Pleural lobes gently convex with three pairs furrowed pleurae; pleural furrows shallow except those of first pair, which are relatively deep, shallow abaxially, and reach pygidial margin in some specimens. Border broad,

flat, well defined by shallow, wide border furrow; width (tr., sag.) of border uniform, equal to one-quarter pygidial length.

Surface of cranium and pygidium covered with dense, fine granules.

Remarks. In addition to the type species, the following have been referred to *Ischyrophyma*: *I. tumida* Whittington, 1965, from the Table Head Formation (Llanvirn) of western Newfoundland; *I. marmorea* Dean, 1970 from a limestone of probable Arenig age in north-eastern Newfoundland; *I. deserta* (Billings 1865) (see Dean 1970, pl. 1, figs. 4, 8, 12) from a boulder of early Ordovician limestone in Quebec; and probably, as noted by Dean (1970), the Swedish Arenig species *Glaphurina? insolita* Tjernvik, 1956. *Ischyrophyma? borealis* Fortey, 1980, from the upper Valhallfonna Formation (Arenig) of Spitzbergen, was reassigned to *Ischyrotoma* Raymond, 1925 by Bruton (1983, p. 218).

In its inflated, strongly down-curved glabella the new species resembles *I. tumida* Whittington (1965, p. 339, pl. 19, figs. 6–12, 15) rather than the type species *I. tuberculata* Whittington (1963, p. 48, pl. 8, figs. 1–10). *I. tumida* differs in: smaller lateral glabellar lobes; parallel-sided glabella, which does not narrow in front of abaxial ends of 1p furrows; narrower, ridge-like anterior border; and more scattered but coarser granules on surface of exoskeleton. The only pygidium so far assigned to *Ischyrophyma* is that figured as *I. marmorea* Dean (1970, pl. 2, fig. 2), which is well segmented, with broad axis and wide border, and is comparable with that of the present species. The cranium of *I. marmorea* resembles that of *I.? zhiqiangi* in the following respects: outline of glabella and occipital ring; small palpebral lobes close to axial furrows; upturned, uniformly wide (sag.) anterior border; and posterior branches of facial suture, which are straight and extend obliquely backwards (see holotype in Dean 1970, pl. 1, figs. 2, 11, 13). *I. marmorea* is distinguished by: presence of four pairs lateral glabellar furrows; lack of an occipital tubercle; ornamentation of more scattered, coarser tubercles; longer 1p lobes; and less inflated glabella. The Newfoundland specimens are much larger than ours, and somewhat distorted, which may account for the two last differences.

Unfortunately the pygidium of *Ischyrophyma tuberculata* has not been found but the holotype (Whittington 1963, pl. 8, figs. 1–3, 5), an enrolled specimen comprising cephalon and seven thoracic segments, has ample space for additional thoracic segments and a pygidium like that of *I. marmorea* and the new species. But the question remains open and the pygidium of *Ischyrophyma* could alternatively be a tiny one, composed of a single segment, as claimed by Fortey (1980a, p. 68). If the latter is the case, the pygidia of *I. marmorea* and *I.? zhiqiangi* may be incorrectly assigned, or both species may have to be excluded from *Ischyrophyma*. A further possibility is that *Ischyrophyma* is a junior subjective synonym of *Celmus* Angelin, 1854, as suggested by Bruton (1983, p. 218). Fortey (1980a, p. 68) was inclined to consider *I. marmorea* a glaphurid, even though the posterior branches of the facial suture are straight and run abaxially backwards. The pygidium in our collection, if correctly assigned, suggests that the new species may be related to the proetids. For the present we follow Whittington (1963) in referring *Ischyrophyma* questionably to the Dimeropygidae, pending a more complete knowledge of its type species.

EXPLANATION OF PLATE 63

Figs. 1–7, 12. *Ischyrophyma? zhiqiangi* sp. nov. Bed 12. 1, cranium, paratype, NI 80664, $\times 8$. 2, 7, cranium, dorsal and right lateral views, holotype, NI 80665, $\times 8$. 3, cranium, paratype, NI 80666, $\times 10$. 4, pygidium, paratype, NI 80667, $\times 10$. 5, pygidium, paratype, NI 80668, $\times 8$. 6, pygidium, paratype, NI 80669, $\times 8$. 12, pygidium, paratype, NI 80670, $\times 10$.

Figs. 8, 9, 11, 13. *Lonchodomas nanus* Zhou in Zhou et al. 1982. Bed 4. 8, cranium, NI 80671, $\times 8$. 9, 11, cranium, dorsal and right lateral views, NI 80672, $\times 8$. 13, cranium, NI 80673, $\times 8$.

Fig. 10. *Bulbaspis* sp. Bed 4. Immature cranium, NI 80674, $\times 12$.



1



2



3



4



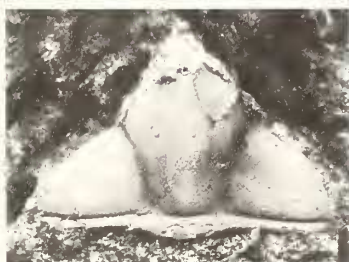
5



6



7



8



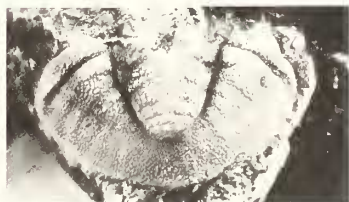
9



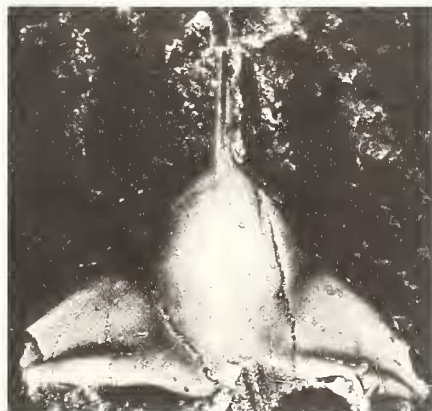
11



10



12



13

Family RAPHIOPHORIDAE Angelin, 1854

Genus LONCHODOMAS Angelin, 1854

Type species. *Ampyx rostratus* Sars, 1835, from the *Ampyx* Limestone (late Llandeilo or early Caradoc) of Bygdøy, Oslo, Norway.

Lonchodomas nanus Zhou in Zhou *et al.* 1982

Plate 63, figs. 8, 9, 11, 13

1982 *Lonchodomas nanus* Zhou in Zhou *et al.*, p. 280, pl. 69, figs. 11 and 12.

Diagnosis. Species of *Lonchodomas* with stout, weakly carinate glabella. Median glabellar spine with deeply incised median groove.

Holotype. Cranidium XITr-173, figured Zhou (in Zhou *et al.* 1982, pl. 69, fig. 12), from the topmost Pingliang Formation (early Caradoc), Shijiezigou, Guyuan County, Ningxia, China.

Figured specimens. Three cranidia, NI 80671–80673, from Bed 4.

Description. Cranidium triangular in outline with length (excluding glabellar spine) less than half maximum width. Glabella weakly carinate, transversely convex, rhombic in plan, extending for up to half its length in front of fixigenae; maximum width across middle of glabella equals 0.7 to 0.85 length and about 0.65 basal width of glabella. Median glabellar spine subquadrate in section, with deeply incised median groove; three closely spaced pairs suboval muscle scars on glabellar flanks extend abaxially to axial furrows. Occipital ring convex, higher than rest of cranidium, and gently curved backwards; occipital furrow distinct, curved forwards laterally. Axial furrows broad, slightly convex laterally, effaced posteriorly where they are indicated by change in slope between posterior border and occipital ring; pair of small, shallow, anterior fossulae sited close to anterolateral corners of glabella. Triangular fixigenae about three-quarters as long as wide, strongly declined anteriorly, gently abaxially, with pair small, circular muscle scars located posteriorly, opposite fulcrum. Posterior border wide (exsag.), flat, confluent with occipital ring, bluntly pointed backwards at fulcrum sited at its mid-points, from which it narrows sharply abaxially; posterior border furrow mostly deep, narrow (exsag.), but effaced near axial furrows. Facial suture curves in broad arcs along anterior margins of fixigenae, turns sharply inwards and slightly backwards at posterolateral corners of cranidium to cross posterior border obliquely and end near fulcrum. Small cranidium (Pl. 63, fig. 8) has narrow (exsag.) posterior border, with fulcrum placed nearer abaxial extremities of fixigenae, and fixigenae are longer, but otherwise agrees well with larger specimen. Surface covered with broadly spaced terrace lines near, and subparallel to, anterior margin of cranidium.

Remarks. *Lonchodomas nanus* strongly resembles *L. blackstonensis* Legg (1976, p. 16, pl. 6, figs. 28, 33) from the Goldwyer Formation (Llanvirn) of Blackstone, Canning Basin, Western Australia, in the outline of the weakly carinate glabella; but the latter species has a shorter (sag.) glabella with median spine that lacks a median groove and is probably rounded in cross section. The Llandeilo or early Caradoc species *L. paenepennatus* Ross (1970, p. 88, pl. 16, figs. 23–27; pl. 17, figs. 1 and 2), from the top part of the Antelope Valley Limestone, and *L. retrolatus* Ross (1967, p. D24, pl. 7, figs. 22–28), from the lower Eureka Quartzite of Nevada, USA are similar in many respects to *L. nanus* but have a much narrower (tr.) glabella. The surface ornamentation of the American species is unknown, and the pygidium of the Chinese species has not been found, so further comparison is impossible. The early Caradoc species *L. tecturmasi* (Weber 1932, p. 6, pl. 4, fig. 43; 1948, p. 18, pl. 2, figs. 20–22, 26; Chugaeva 1958, p. 32, pl. 2, figs. 3–5) from Kazakhstan resembles the two Nevada species in the outline of cranidium and glabella, but the latter is strongly carinate and thus easily distinguished from that of *L. nanus*. The holotype of *L. nanus* has a slightly narrower (tr.) glabella and better-defined occipital ring than the present material from Chedao, but is slightly crushed and much larger.

Genus BULBASPIS Chugaeva, 1958

Type species. *Ampyx bulbifer* Weber, 1932, from the Djebagly 'horizon' (Llandeilo) of the Djebagly Range, southern Kazakhstan, U.S.S.R.

Bulbaspis sp. indet.

Plate 63, fig. 10

Figured specimen. Cranidium, NI 80674, from Bed 4.

Remarks. Cranidium has strongly carinate, narrow (tr.) glabella, subrhombic in outline; fixigenae wide (tr.), gently arched forwards; posterior border straight, ridge-like. All these features suggest that the specimen is possibly referable to *Bulbaspis*. One of the latter's most important characters is the presence of a median glabellar bulb but, as noted by Zhang (1981, p. 202), juvenile specimens show only a median spine as in *Lonchodomas*. The present specimen, about 3 mm wide and 1.6 mm long, is apparently immature and the tip of the glabella is not preserved.

Species of *Bulbaspis* from Llanvirn to Caradoc in age have been reported from Kazakhstan (Chugaeva 1958; see also Weber 1932, 1948), Inner Mongolia, China (Lu in Lu *et al.* 1976), north-west China (Zhou in Zhou *et al.* 1982; Zhang 1981), southern Tasmania, Australia (Burrett *et al.* 1983) and possibly Langkawi Island, Malaysia (Kobayashi and Hamada 1978). Among them *Bulbaspis ovulum* (Weber 1948, p. 15, pl. 2, figs. 6–10) from the Kopalin and Karakan horizons (Llanvirn–early Llandeilo) is closely comparable with our specimen in the outline of the glabella but the fixigenae are longer; the glabella is widest opposite its midpoint in the Chinese specimen, but at a point one third of the glabellar length (excluding bulb) from its anterior end in *B. ovulum*.

Family HAMMATOCNEMIDAE Kielan, 1960

Genus HAMMATOCNEMIS Kielan, 1960

Type species. *Hammatocnemis tetrasulcatus* Kielan, 1960, from the *Staurocephalus clavifrons* Zone (Ashgill), Brzezinski, Poland.

Remarks. The oldest known member of the genus (Lu and Zhou 1979) is believed to be *Hammatocnemis primitivus primitivus* Lu, 1975, from the Arenig of the Yangtze region of China. On the basis of the structure of the preoccipital ring, the remaining, younger species fall into two groups: 1. species with a pair of isolated preoccipital (1p) lobes but without an intervening median 'ring', found only in the Yangtze region, China; and 2. species with entire median preoccipital ring between the 1p lateral glabellar lobes, widely distributed in the Inner Mongolia region of north China, northwest China, Uzbekistan and Kazakhstan, southern U.S.S.R., and Poland.

Group 1 includes: *H. huayinshanensis* Lu in Lu and Zhang 1974; *L. yangtzeensis* Lu in Lu and Zhang 1974 (= *H. nanzhengensis* Zhou in Li *et al.* 1975 = *H. cf. pagodus* Chen in Li *et al.* 1975); *H. decorosus* Lu in Lu and Chang 1974 (= *H. tetrasulcatus* Sheng, 1964 *non* Kielan 1960 = *H. liangshanensis* Chen in Li *et al.* 1975, and probably = *H. sinensis* Han, 1980); *H. ovatus* Sheng, 1964 (described first as *H. tetrasulcatus ovatus* = *H. orientalis* Chen in Li *et al.* 1975 = *H. pagodus* Chen in Li *et al.* 1975 = *H. ? tudilingensis* Chen in Li *et al.* 1975 = *H. hexianensis* Q. Z. Zhang in Qiu *et al.* 1983); and *H. longicervix* Zhou in Lu *et al.* 1976.

Group 2 includes: *H. primitivus extraneus* Lu and Zhou, 1979; *H. intermedius* Lu and Zhou, 1979; *H. tetrasulcatus* Kielan, 1960; *H. globosus* Abdullaev, 1972; *H. kanlingensis* Zhang, 1981; and *H. obsoletus* sp. nov. (described below).

Hammatocnemis obsoletus sp. nov.

Plate 64, figs. 1–4, 8, 9, 11, 12; Plate 65, fig. 11

Holotype. Cranidium, NI 80675 (Pl. 64, figs. 1 and 2), from Bed 4.

Paratypes. Five cranidia (NI 80676, 80677, 80678, 80679, 80702) and two pygidia (NI 80680, 80681) from Bed 4.

Name. Latin *obsoletus*, *a*, *um*, obsolete, referring to the lack of deep 3p and 4p glabellar furrows.

Diagnosis. *Hammatocnemis* species with 3p and 4p lateral glabellar furrows faintly defined. Pre-occipital segment wide (sag.) with 1p lateral glabellar lobes weakly defined. Glabellar surface smooth or with scattered small granules.

Description. Glabella gently convex, divided into small, parallel-sided preoccipital ring and large anterior lobe that extends well forwards and is broadly rounded frontally. Preoccipital ring flat, low, its length (sag.) half that of occipital ring; it widens (exsag.) slightly abaxially to form pair of weakly convex, poorly defined, subquadrate 1p lobes. Preoccipital (or 1p transglabellar) furrow transverse in direction, deeply incised laterally, shallow medially. Anterior lobe of glabella (i.e. portion of glabella in front of 1p furrows) nearly as long as wide, widest across anterolateral angles, where 1.6–1.8 times width (tr.) of occipital ring. Three equidistant pairs lateral glabellar furrows decrease in length anteriorly; 2p pair narrow, deep, and run slightly forwards adaxially; 3p pair faint, parallel to 2p; 4p pair very faint, directed slightly forwards adaxially and sited opposite anterior ends of palpebral lobes. Occipital ring about three times as wide (tr.) as long (sag.) and wider (tr.) than base of glabella; its anterior margin is curved forwards medially, where length (sag.) about 0.22 that of glabella, and straight posterior margin turns forwards near axial furrows; there is a tiny median tubercle. Occipital furrow deep, becoming slightly shallower medially. Axial furrows deep, broad. Narrow (tr.) palpebral lobes, well defined by deep palpebral furrows and elevated above fixigenae, located between 2p and 4p glabellar furrows. Palpebral areas of fixigenae triangular; subrectangular posterior areas decline steeply abaxially from fulcra and occupy one-third basal width and one-quarter median length of cranium; posterior border gently convex, widens (exsag.) abaxially, bounded by deep, wide posterior border furrow. Anterior branches of facial suture run along axial furrows before turning adaxially; posterior branches curve strongly back abaxially.

Pygidium two-and-a-half times as wide as long, widest posteriorly, where posterior margin curved, slightly concave. Low, triangular axis has frontal breadth about one-third that of pygidium and extends to posterior margin of pygidium; there are four transversely rectangular axial rings and rounded terminal piece in addition to articulating half-ring. Ring furrows deep, arched forwards; axial furrows distinct, narrow. Laterally declined pleural lobes comprise four pleurae that are separated by distinct interpleural furrows and turn backwards abaxially; tips of first three pleurae extend slightly beyond posterior pygidial margin, but only those of first pleura form free points.

Surface of cranium and pygidium smooth or covered with scattered granules.

Remarks. The species appears to occupy an isolated position within the genus. It resembles older species such as the Llanvirn *Hammatocnemis intermedius* Lu and Zhou (1979, p. 427, pl. 2, fig. 9; text-fig. 6) in having the glabellar outline less constricted at the 2p furrows, so that the width there is nearly the same as that of the preoccipital (1p) segment; and the 2p to 4p glabellar furrows are longer than those of younger species.

The pygidium closely resembles that of younger species such as *H. tetrasulcatus* Kielan (1960, p. 141, pl. 25, fig. 3; pl. 26, figs. 2, 4; pl. 27, figs. 6–8), but the anterior three pleurae of *H. obsoletus* extend further backwards, beyond the posterior pygidial margin, as seen in older species such as *H. primitivus primitivus* Lu (1975, p. 231, pl. 45, figs. 4–14) and *H. primitivus extraneus* Lu and Zhou (1979, p. 426, pl. 1, figs. 1–13; pl. 2, figs. 1–8), though the second and third pleurae do not end in free points in *H. obsoletus*.

EXPLANATION OF PLATE 64

Figs. 1–4, 8, 9, 11, 12. *Hammatocnemis obsoletus* sp. nov. Bed 4. 1 and 2, cranium, dorsal and right lateral views, holotype, NI 80675, $\times 8$. 3, cranium, paratype, NI 80676, $\times 6$. 4, cranium, paratype, NI 80677, $\times 8$. 8, cranium, paratype, NI 80678, $\times 6$. 9, cranium, paratype, NI 80679, $\times 6$. 11, pygidium, paratype, NI 80680, $\times 10$. 12, pygidium, paratype, NI 80681, $\times 6$.

Figs. 5–7, 10. *Hammatocnemis kanlingensis* Zhang, 1981. Bed 4. 5 and 6, cranium, right lateral and dorsal views, NI 80682, $\times 8$. 7, cranium, NI 80683, $\times 5$. 10, pygidium, NI 80684, $\times 4$.

Figs. 13–15. *Hammatocnemis kelleri* (Koroleva, 1959). Bed 12. 13 and 14, cranium, right lateral and dorsal views, NI 80685, $\times 10$. 15, cranium, NI 80686, $\times 8$.



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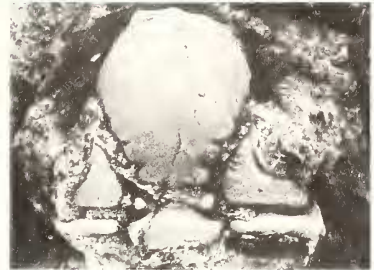
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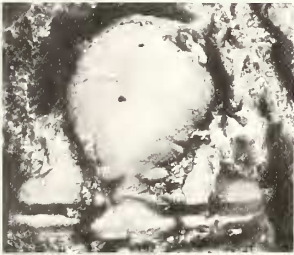
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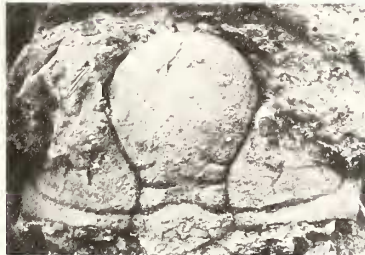
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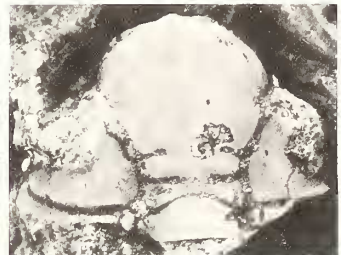
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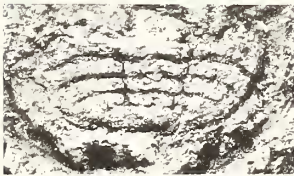
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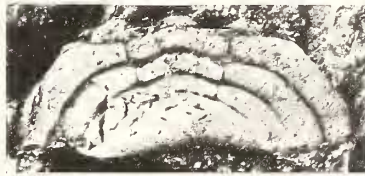
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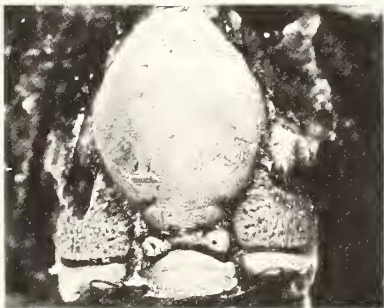
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Hammatocnemis kanlingensis Zhang, 1981

Plate 64, figs. 5-7, 10

- 1979 *Hammatocnemis tetrasulcatus* Kielan; Lu and Zhou, p. 428, pl. 2, figs. 10, 11, *non* Kielan, 1960.
 1981 *Hammatocnemis kanlingensis* Zhang, p. 209, pl. 77, figs. 5-7.

Holotype. Cranidium, XTR 344, figured Zhang (1981, pl. 77, fig. 7), from the Qilang Formation of Kanling, Keping county, Xinjiang, China.

Figured specimens. Two cranidia (NI 80682, 80683) and one pygidium (NI 80684), from Bed 4.

Remarks. The species is generally comparable with *H. tetrasulcatus* Kielan, 1960 but the anterior lobe of the glabella is longer (sag.), oval in plan, and less expanded forwards. *H. kanlingensis* also resembles *H. ovatus* Sheng (1964, p. 560, pl. 2, figs. 2a-c; Lu 1975, p. 441, pl. 45, figs. 1-3), from the Caradoc to early Ashgill of the Yangtze region, from which it differs in having the preoccipital (= 1p) lateral glabellar lobes linked by a prominent median ring.

Specimens from the Ashgill of central Asia determined as *H. tetrasulcatus* by Apollonov (1974, p. 62, pl. 13, figs. 1-8; pl. 14, figs. 1-6) and by Petrunina (in Repina *et al.* 1975, p. 219, pl. 46, figs. 1-3, 6-14) differ from the Polish species in the shape of the anterior lobe of the glabella and may be synonymous with *H. kanlingensis*.

Genus *Ovalocephalus* Koroleva, 1959

Type species. *Ovalocephalus kelleri* Koroleva, 1959, from the late Caradoc of Kazakhstan and Uzbekistan.

Remarks. One of the diagnostic features of *Ovalocephalus* appears to be the lack of 3p and 4p lateral glabellar furrows, but judging from the present material assigned to the type species, *O. kelleri*, 3p and 4p are represented by small pits beside the axial furrows on the external surface or by noticeable muscle scars on the exfoliated surface, as seen also in an Ashgill specimen from Kazakhstan figured by Apollonov (1974, pl. 13, fig. 9). Both the length and the degree of development of the anterior lateral glabellar furrows vary in *Hammatocnemis*. According to Lu and Zhou (1979, p. 423) one of the evolutionary trends affecting the glabella is the shortening of the anterior glabellar furrows; similar effacement of the corresponding furrows can be seen in, for example, *H. obsoletus* sp. nov. and seems to be of no more than specific importance. Other diagnostic features of *Ovalocephalus* are the presence of genal spines (seen also in our material) and the sub-rounded anterior margin of the glabella. However, genal spines such as are developed in juvenile specimens of *Hammatocnemis* (see Kielan 1960, pl. 25, fig. 3; Lu and Zhou 1979, pl. 3, fig. 10) exist also in some mature cranidia of the genus, for example, *H. longicervix* Zhou (in Lu *et al.* 1976, p. 75, pl. 13, fig. 13), though they are shorter. The shape of the glabella in *Hammatocnemis* varies both between and within species. Present material indicates that the frontal glabellar lobe of *Ovalocephalus* is oval to rounded-rhombic in outline, and is more or less comparable with some specimens of *Hammatocnemis ovatus* Sheng (see Lu 1975, pl. 45, figs. 2 and 3). All the pygidia in the present collection agree with that of *Hammatocnemis*. It seems likely that *Hammatocnemis* may eventually be considered a junior subjective synonym of *Ovalocephalus*.

Ovalocephalus kelleri Koroleva, 1959

Plate 64, figs. 13-15; Plate 65, figs. 5, 13

- 1959 *Ovalocephalus kelleri* Koroleva, p. 1316, text-fig. 3.
 1972 *Ovalocephalus kelleri* Koroleva; Abdullaev, p. 110, pl. 45, fig. 1.
 1974 *Ovalocephalus kelleri* Koroleva; Apollonov, p. 65, pl. 13, fig. 9.
 1975 *Ovalocephalus kelleri* Koroleva; Petrunina in Repina *et al.*, p. 220, pl. 46, figs. 15 and 16.

Holotype. Cranidium, figured Koroleva (1959, text-fig. 3a), from a limestone of late Caradoc age in northern Kazakhstan.

Figured specimens. Three cranidia (NI 80685, 80686, 80699) and one pygidium (NI 80700) from Bed 12.

Remarks. Cranidia in the present collection are indistinguishable from the holotype. This species is characterized by the longer anterior lobe of the glabella, the effaced 3p and 4p furrows, and the presence of a pair of prominent genal spines. The outline of the anterior glabellar lobe varies from oval (Pl. 64, fig. 15) to rounded—rhombic (Pl. 64, figs. 13 and 14; Pl. 65, fig. 5), and the anterior glabellar margin is strongly convex forwards.

Family ENCRINURIDAE Angelin, 1854

Subfamily CYBELINAE Holliday, 1942

Genus LYRAPYGE Fortey, 1980

Type species. *Lyrapyge ebriosus* Fortey, 1980, from the middle part of the Olenidsletta Member (middle Arenig), Valhallfonna Formation, northern Ny Friesland, Spitsbergen.

Lyrapyge? gaoluoensis (Zhou in Zhou *et al.* 1977)

Plate 65, figs. 1, 2, 9, 14

1975 *Atractopyge* sp. Lu, p. 445, pl. 46, fig. 1.

1977 *Atractopyge gaoluoensis* Zhou in Zhou *et al.*, p. 260, pl. 79, figs. 1a, b, and 2.

1978 *Atractopyge gaoluoensis* Zhou; Xia, p. 182, pl. 36, figs. 13–15.

1981 *Atractopyge gaoluoensis* Zhou; Lu and Zhou, p. 19, pl. 3, fig. 9.

1983 *Atractopyge xiangnanensis* Q. Z. Zhang in Qiu *et al.*, p. 242, pl. 83, fig. 3.

?1983 *Atractopyge gaoluoensis* Zhou; Q. Z. Zhang in Qiu *et al.*, p. 242, pl. 83, fig. 4.

Holotype. Dorsal shield, II IV 70198, figured Zhou in Zhou *et al.* (1977, pl. 79, fig. 2), from the Linhsiang Formation (early Ashgill), Gaoluo, Xuan County, Hupei Province, China.

Figured specimens. Two cranidia (NI 80691, 80692) and two pygidia (NI 80693, 80694) from Bed 12.

Description. Glabella transversely convex, subparallel-sided posteriorly, expands strongly from adaxial extremities of palpebral ridges into a wide frontal lobe that is highest posteriorly and declines gently forwards. Maximum glabellar width (between anterolateral corners of glabella) is about twice the basal glabellar width and equal to the glabellar length. Three pairs short, deep, pit-like lateral glabellar furrows are equispaced on flanks of posterior lobe of glabella. 3p furrows bifurcate adaxially and shallow abaxially, their faint anterior branches located beside distal ends of eye ridges. Distinct, deep occipital furrow curves forwards abaxially. Occipital ring lenticular in plan, its length (sag.) one seventh that of cranidium. Axial furrows deep posteriorly, slightly shallower anteriorly, with pair of anterior pits sited in line with centre of frontal glabellar lobe. Narrow (sag.), upturned anterior border narrows laterally and is well defined medially by anterior border furrow. Conspicuous palpebral ridges run obliquely backwards abaxially. Anterior branches of facial suture converge forwards and turn inwards.

Pygidium subtriangular in plan, about 1.4 times as wide as long. Strongly convex, conical axis occupies about one-quarter anterior breadth of pygidium and comprises five well-defined axial rings and a terminal piece; ring furrows deep laterally, shallow medially. Axial furrow deep, broad. Pleural regions consist of pair anterior half ribs, three pairs ribs, and a triangular post-axial piece. Ribs of first pair are transverse adaxially but curve backwards and slightly inwards abaxially; remaining ribs curve backwards and inwards; pleural furrow short (tr.), about half length (tr.) of pleurae; deep, long interpleural furrows separate ribs into two bands, of which the anterior bands are highly convex, widen to become spatulate posteriorly, and terminate in free points.

Surface finely granular except for fixigenae, which are densely pitted.

Remarks. The species resembles *Lyrapyge ebriosus* Fortey (1980a, p. 100, pl. 23, figs. 10–14; pl. 24, figs. 1–9) rather than *Atractopyge verrucosa* (Dalman), type species of *Atractopyge*, the holotype of which, from the Ashgill of south Wales, was re-figured by Dean (1974, p. 97, text-fig. 4a, b). *L. gaoluoensis* differs from *L. ebriosus* as follows: absence of anteromedian, longitudinal glabellar furrow; absence of preglabellar furrow, though its abaxial extremities are indicated by the anterior pits; much narrower (tr.) posterior lobe of glabella; much shorter lateral glabellar furrows; three instead of four pairs pleural ribs; pygidial spines spatulate.

Family LICHIDAE Hawle and Corda, 1847
 Subfamily LICHINAE Hawle and Corda, 1847
 Genus *Lichas* Dalman, 1827

Type species. *Entomostracites laciniatus* Wahlenberg, 1818, from the *Dalmanitina* Beds (Ashgill) of Bestorp, Mosseberg, Sweden.

Lichas aff. *laciniatus* (Wahlenberg, 1818)

Plate 65, figs. 15–18

Figured specimens. Two cranidia (NI 80688, 80690), one hypostoma (NI 80689) and one pygidium (NI 80687), all from Bed 12.

Remarks. Cranidium has central glabellar lobe expanded gradually forwards, its neck narrower than the mean width of, and set lower than, the lateral glabellar lobes. According to Warburg (1925, p. 306) these features suggest *L. laciniatus* rather than *L. affinis* Angelin, 1854. *L. laciniatus* has been recorded from the Ashgill to lowest Llandovery of Sweden (Warburg 1925, 1939), northern England (Reed 1896, as *Lichas conformis* var. *keisleyensis* Reed; Temple 1969) and eastern Ireland (Dean 1974). Specimens from different areas exhibit slightly different surface sculpture. Surface of the present cranidium, covered with densely grouped, small, low granules of different sizes, is comparable with a specimen figured by Temple (1969, pl. 2, figs. 1–9) but differs from those figured by Warburg (1939, pl. 9, fig. 3a, b) and Dean (1974, pl. 34, figs. 2, 3, 9), which show larger but sparsely distributed granules. The Chinese hypostoma resembles that of a Silurian specimen (Temple 1969, pl. 3, figs. 1–3) in the branched middle furrow, but the posterior branches turn adaxially behind the maculae and meet in a distinct transverse furrow. The associated small pygidium from China is shorter (sag.), more broadly rounded posteriorly, with an additional pair of tiny, closely spaced posterior spines but otherwise agrees well with the holotype (Wahlenberg 1818, pl. 2, fig. 2*; Warburg 1925, text-fig. 20; 1939, pl. 9, fig. 1; Temple 1969, pl. 3, fig. 5). However, the specimen, only 2.3 mm wide and 1.4 mm long, is much smaller than any previously recorded pygidium of *L. laciniatus*.

Family ISCOLIDAE Angelin, 1854
 Genus CYPHONISCUS Salter, 1853

Type species. *Cyphoniscus socialis* Salter, 1853, from the Chair of Kildare Limestone (Ashgill) of Kildare, eastern Ireland.

Cyphoniscus cf. *socialis* Salter, 1853

Plate 65, figs. 8, 12

Figured specimen. Cranidium, NI 80701, from Bed 4.

EXPLANATION OF PLATE 65

- Figs. 1, 2, 9, 14. *Lyrapyge? gaoluensis* (Zhou in Zhou *et al.* 1977). Bed 12. 1, cranidium, NI 80691, $\times 5$. 2, cranidium, NI 80692, $\times 8$. 9, pygidium, NI 80693, $\times 6$. 14, pygidium, NI 80694, $\times 10$.
 Figs. 3, 4, 6, 7, 10. *Paratiresias turkestanicus* Petrunina in Repina *et al.* 1975. Bed 12. 3, cranidium, NI 80695, $\times 8$. 4, cranidium, NI 80696, $\times 6$. 6 and 7, cranidium, dorsal and right lateral views, NI 80697, $\times 6$. 10, cranidium, NI 80698, $\times 6$.
 Figs. 5, 13. *Ovalocephalus kelleri* Koroleva, 1959. Bed 12. 5, cranidium, NI 80699, $\times 5$. 13, pygidium, NI 80700, $\times 10$.
 Figs. 8, 12. *Cyphoniscus* cf. *socialis* Salter, 1853. Bed 4. Cranidium, right lateral and dorsal views, NI 80701, $\times 10$.
 Fig. 11. *Hammatocnemis obsoletus* sp. nov. Bed 4. Small cranidium, paratype, NI 80702, $\times 12$.
 Figs. 15–18. *Lichas* aff. *laciniatus* (Wahlenberg, 1818). Bed 12. 15, juvenile pygidium, NI 80687, $\times 12$. 16, cranidium, NI 80688, $\times 5$. 17, hypostoma, NI 80689, $\times 12$. 18, cranidium, NI 80690, $\times 6$.



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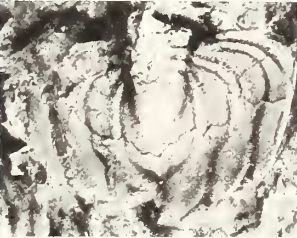
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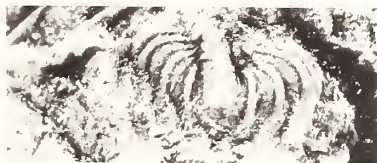
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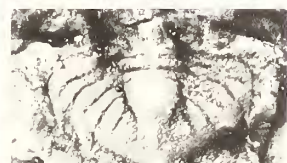
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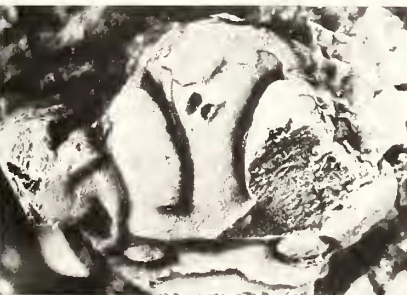
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Remarks. The single cranium has a proportionately longer glabella and the palpebral lobes are situated slightly further forwards, but otherwise agrees well with the lectotype and other cranidia from the Chair of Kildare Limestone (Salter 1853, pl. 9, figs. 1, 3, 4, 6, 7; Whittington 1956, pl. 130, figs. 1-9, 11; Dean 1971, pl. 20, figs. 11, 13; pl. 21, figs. 1, 4-6). *C. socialis* has also been recorded from the Ashgill of Uzbekistan (Abdullaev 1972), Kazakhstan (Apollonov 1974), and southern Tyan Shan (Petrunina in Repina *et al.* 1975). Cranidia figured by both Petrunina (in Repina *et al.* 1975, pl. 48, figs. 17-20) and Apollonov (1974, pl. 17, figs. 4, 8) show the glabella more elongated than that of the lectotype, and in this respect agree with our specimen. Other cranidia figured by Apollonov (1974, pl. 17, figs. 6, 7, 9) compare closely with those from the type locality and may indicate intraspecific variation in the ratio of glabellar length : width. If so, the present specimen would be referable to *C. socialis sensu stricto*, but for the time being it is left under open nomenclature.

Genus PARATIRESIAS Petrunina in Repina *et al.* 1975

Type species. *Paratiresias turkestanicus* Petrunina in Repina *et al.* 1975, from the *Kielanella-Tretaspis* Beds of Ulugtay District, Turkestan and Alai Ridges (southern Tyan Shan), Uzbek SSR.

Remarks. The diagnosis given by Petrunina (in Repina *et al.* 1975, p. 227) is as follows (free translation from the Russian): 'Cranidium elongated-trapezoid in outline with entire anterior border arched forwards. Glabella evenly convex, expanding forwards. Axial furrows distinct. Preglabellar field absent. Anterior border quite wide, convex, evenly curved. Anterior border shallow. Fixigena narrow, strongly sloping downwards. Palpebral lobe small, forwardly located. Posterior border strongly widening abaxially. Anterior branches of facial sutures weakly divergent. Surface covered with fine lines.' *Tiresias* M'Coy, 1846 and *Holdenia* Cooper, 1953 are considered synonymous (Dean 1962, p. 342), but as the former is preoccupied by *Tiresias* Stephens, 1833 (see Sherborn 1931, p. 6528) *Holdenia* should be used instead. Characteristic features of *Paratiresias* that differ from those of *Holdenia* include: glabella less expanded forwards; narrower fixigenae; presence of well-defined anterior border; anterior branches of facial suture divergent.

Cranidia described below are essentially indistinguishable from the holotype of the type species but are better preserved and provide additional detail. The anterior border furrow is, in fact, deep and broad as shown in the original material (Petrunina in Repina *et al.* 1975, pl. 47, figs. 1, 4-7). As in *Holdenia* there is a median occipital tubercle and three pairs of smooth patches on the flanks of the glabella represent glabellar furrows. The Bertillon pattern ornamentation of the exoskeletal surface is comparable with that of *Holdenia* (see Dean 1962, pl. 49, figs. 1-8), but the raised lines are more densely grouped and there are no granules on the intervening spaces.

Paratiresias turkestanicus Petrunina in Repina *et al.* 1975

Plate 65, figs. 3, 4, 6, 7, 10

1975 *Paratiresias turkestanicus* Petrunina in Repina *et al.* p. 227, pl. 47, figs. 1, 4-7.

Figured specimens. Four cranidia (NI 80695-80698) from Bed 12.

Description. Cranium trapezoidal in plan, longer than wide, broadly rounded anteriorly. Glabella strongly convex transversely, gently rounded in profile; its outline is suboval, transversely straight posteriorly, broadly rounded anteriorly, gently expanded forwards, about four-fifths as long as wide with maximum width developed at one third length of glabella from its anterior margin. Three pairs lateral glabellar furrows represented by smooth, suboval patches on flanks of glabella; 3p pair directed forwards and sited opposite palpebral lobes; 2p pair transverse, opposite centre of glabella; 1p pair subparallel to 2p pair and widen (exsag.) abaxially. Occipital ring carries a tiny median tubercle, has sagittal length about one-sixth that of glabella, and shortens (exsag.) and curves forwards abaxially. Occipital furrow deeply incised. Axial furrows deep and wide, and become still wider posteriorly. Fixigenae steeply declined, sub-triangular in plan, basal width one-fifth that of cranium and three times anterior width. Palpebral lobes small, very narrow, raised, abaxially curved, their length (exsag.) equal to that of anterior border; anterior ends of palpebral lobes just reach

anterior border furrow. Anterior branches of facial suture very short; posterior branches long, straight, extending across posterior part of lateral border to cut posterior border distally. Anterior border convex, semicircular in cross-section, slightly narrower (sag.) medially, and well defined by deep, broad (sag.) anterior border furrow. Posterior border widens (exsag.) laterally.

Surface covered with scattered granules; anterior border, glabella and occipital ring carry Bertillon pattern of anastomosing raised lines subparallel to glabellar margins. Similar anastomosing raised lines are more densely grouped on the fixigenae, subparallel to the lateral margins of the cranidium.

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REFERENCES

- ABDULLAEV, R. N. 1972. Trilobites of the Upper Ordovician of Bukantan. 103–126. In MASIMOV, A. S. and ABDULLAEV, R. N. (eds.). *New data on the fauna of the Palaeozoic and Mesozoic of Uzbekistan*. Akad. Nauk. Uzb. SSR Inst. Geol. Geophys., FAN, Tashkent, 1–142. [In Russian.]
- ANGELIN, N. P. 1851. *Palaeontologia Suecica I. Iconographia Crustaceorum formationis transitionis, Fasc 1*, 1–24. Samson and Wallin, Lund.
- 1854. *Palaeontologia Scandinavica I. Crustacea Formationis transitionis, Fasc 2*, 21–92. Samson and Wallin, Lund.
- APOLLONOV, M. K. 1974. *Ashgill trilobites of Kazakhstan*. Izd. 'Nauka' Kazakhskoi SSR, Alma-Ata, 1–136. [In Russian.]
- BARRANDE, J. 1846. *Notice préliminaire sur le Système silurien et les Trilobites de Bohême*, vi + 97, pp. Leipsic.
- 1852. *Système silurien du centre de la Bohême. 1ère partie. Recherches paléontologiques. Vol. 1. Crustacés, Trilobites*, xxx + 935 pp. Prague and Paris.
- BILLINGS, E. 1861–1865. *Palaeozoic Fossils. Volume 1. Containing descriptions and figures of new or little known species of organic remains from the Silurian rocks*, 426 pp. Montreal.
- BRÖGGER, W. C. 1882. Die silurischen Etagen 2 und 3 im Kristiania-gebiet und auf Eker, ihre Gliederung, Fossilien, Schichtenstörungen und Contactmetamorfosen. Univ.-Programm (Christiania), 1–376.
- BRUTON, D. L. 1976. The trilobite genus *Phillipsinella* from the Ordovician of Scandinavia and Great Britain. *Palaeontology* **19**, 699–18.
- 1983. The morphology of *Celmus* (Trilobita) and its classification, 213–219. In BRIGGS, D. E. G. and LANE, P. D. (eds.). *Trilobites and other early arthropods. Spec. Pap. Palaeont.* **30**, 276 pp.
- BURMEISTER, H. 1843. *Die Organisation der Trilobiten*. 147 pp. Berlin.
- BURRETT, C., STAIT, B. and LAURIE, J. 1983. Trilobites and microfossils from the Middle Ordovician of Surprise Bay, southern Tasmania, Australia. *Mem. Ass. Australas. Palaeontols.* **1**, 177–193.
- BUTTS, C. 1926. The Paleozoic rocks. Geology of Alabama. *Spec. Rep. geol. Surv. Ala.* **14**, 41–230.
- CALLAWAY, C. 1877. On a new area of Upper Cambrian rocks in South Shropshire, with a description of a new fauna. *Q. Jl. geol. Soc. Lond.* **33**, 652–672.
- CHANG RIDONG. 1962. Several nautiloid species from the Middle Ordovician of Huanxian, Giansu. *Aeta palaeont. sin.* **10** (4), 514–523. [In Chinese with Russian summary.]
- CHANG WENTANG. 1962. Ordovician of China. Science Press, Beijing, 161 pp. [In Chinese.]
- CHANG WENTANG and FAN, C. S. 1960. Class Trilobita of the Ordovician and Silurian periods of the Chilian Mountains. In *Geological Gazetteer of the Chilian Mountains* **4** (1), 83–148. Science Press, Beijing. [In Chinese.]
- CHATTERTON, B. D. E. 1980. Ontogenetic studies of Middle Ordovician trilobites from the Esbataottine Formation, Mackenzie Mountains, Canada. *Palaeontographica* **171**, 1–74.
- and LUDVIGSEN, R. 1976. Silicified Middle Ordovician trilobites from the South Nahanni River area, District of Mackenzie, Canada. *Palaeontographica* **A154**, 1–106.
- CHUGAEVA, M. N. 1958. The Ordovician of Kazakhstan. III: The Ordovician trilobites of the Chu-Ili Mountains. *Trudy geol. Inst. Acad. Nauk S.S.S.R.* **9**, 5–138. [In Russian.]

- COOPER, B. N. 1953. Trilobites from the Lower Champlainian formations of the Appalachian Valley. *Mem. geol. Soc. Am.* **55**, 1–69.
- COOPER, G. A. and KINDLE, C. H. 1936. New brachiopods and trilobites from the Upper Ordovician of Percé, Quebec. *J. Paleont.* **10**, 348–372.
- DALMAN, J. W. 1827. Om Palaeaderna, eller de så kallade Trilobiterna. *K. Svenska Vetensk Akad. Handl.* **1**, 113–152, 226–294.
- DEAN, W. T. 1962. The Ordovician trilobite genus *Tiresias* M'Coy, 1846. *Palaeontology*, **5**, 340–343.
- 1966. The Lower Ordovician stratigraphy and trilobites of the Landeyran Valley and the neighbouring district of the Montagne Noire, south-western France. *Bull. Br. Mus. nat. Hist. (Geol.)*, **12**, 247–353.
- 1970. Lower Ordovician trilobites from the vicinity of South Catcher Pond, northeastern Newfoundland. *Geol. Surv. Pap. Can.* 70-44, 1–11.
- 1971. The trilobites of the Chair of Kildare Limestone (Upper Ordovician) of eastern Ireland. 1. *Palaeontogr. Soc. [Monogr.]* 1–60.
- 1972. The isocolid trilobites *Cyphoniscus* Salter 1853 and *Effnaspis* gen. nov. in the Appalachian region of Canada and U.S.A. *Can. J. Earth Sci.* **9**, 415–421.
- 1973. Ordovician trilobites from the Keele Range, northwestern Yukon Territory. *Bull. geol. Surv. Can.* **223**, 1–43.
- 1974. The trilobites of the Chair of Kildare Limestone (Upper Ordovician) of eastern Ireland. 2. *Palaeontogr. Soc. [Monogr.]*, 61–98.
- 1978. The trilobites of the Chair of Kildare Limestone (Upper Ordovician) of eastern Ireland. 3. *Palaeontogr. Soc. [Monogr.]*, 99–129.
- ELLES, G. L. and WOOD, E. M. T. 1904. A monograph of British Graptolites. 4. *Palaeontogr. Soc. [Monogr.]*, liii–lxxii, 135–180.
- FORTEY, R. A. 1975a. The Ordovician trilobites of Spitsbergen. II. Asaphidae, Nileidae, Raphiophoridae and Telephiniidae of the Valhallfonna Formation. *Norsk Polarinst. Skr.* **163**, 1–207.
- 1975b. Early Ordovician trilobite communities. *Fossils and Strata*, **4**, 339–360.
- 1980a. The Ordovician trilobites of Spitsbergen. III. Remaining trilobites of the Valhallfonna Formation. *Norsk Polarinst. Skr.* **171**, 1–163.
- 1980b. Generic longevity in Lower Ordovician trilobites: relation to environment. *Paleobiology* **6**, 24–31.
- HAN NAIREN. 1980. On the exoskeleton of *Hammatocnemis*. *Geol. Rev.* **26**, 183–189. [In Chinese.]
- HAWLE, J. and CORDA, A. J. C. 1847. *Prodrom einer Monographie der böhmischen Trilobiten*. 176 pp. J. G. Calve, Prague.
- HOLLIDAY, S. 1942. Ordovician trilobites from Nevada. *J. Paleont.* **16**, 471–478.
- HOLM, G. 1882. De svenske arten af Trilobitslagtet *Iliaenus* (Dalman). *K. Svenska Vetensk Akad. Handl.* **7**, 1–148.
- 1886. Illaeniden. Revision der Ostbaltischen silurischen Trilobiten von Fr. Schmidt. Abt. III. *Mém. Acad. Sci. St. Petersb.* **33**, 1–173.
- HOWELL, B. F. 1935. Cambrian and Ordovician trilobites from Hérault, southern France. *J. Paleont.* **9**, 222–238.
- HUANG, T. K., JEN CHISHUN, JIANG CHUNFA, CHANG CHIMENG and XU ZHIQIN. 1977. An outline of the tectonic characteristics of China. *Acta geol. sin.*, 1972, 117–135. [In Chinese with English abstract.]
- HUGHES, C. P. 1979. The Ordovician trilobite faunas of the Builth-Llandrindod inlier, central Wales. *Bull. Br. Mus. nat. Hist. (Geol.)*, **32**, 109–181.
- HUPÉ, P. 1953. Classification des trilobites. *Annls Paléont.* **39**, 61–168.
- INGHAM, J. K. 1970. The Upper Ordovician trilobites from the Cautley and Dent districts of Westmorland and Yorkshire. 1. *Palaeontogr. Soc. [Monogr.]*, 1–58.
- JAEKEL, O. 1909. Ueber die Agnostiden. *Z. dt. geol. Ges.* **61**, 380–401.
- JEN CHISHUN, JIANG CHUNFA, ZHANG ZHENGKUN and QIN DEYU. 1980. *The geotectonic evolution of China*. 124 pp. Geological Publishing House, Beijing. [In Chinese.]
- JII ZAILIANG. 1982. Stratigraphical distribution and range of the trilobite family Phillipsinellidae in South China. *Bull. Inst. geol. Chinese Acad. Sci.* **6**, 57–68. [In Chinese with English abstract.]
- KIELAN, Z. 1960. Upper Ordovician trilobites from Poland and some related forms from Bohemia and Scandinavia. *Palaeont. Pol.* **11**, 1–198.
- KOBAYASHI, T. 1935. The Cambro-Ordovician formations and faunas of South Chosen. *Palaeont.*, Pt. 3. Cambrian faunas of South Chosen with special study on the Cambrian trilobite genera and families. *J. Fac. Sci. Imp. Univ. Tokyo*, **4**, 49–344.

- and HAMADA, T. 1978. Upper Ordovician trilobites from the Langkawi Island, Malaysia. *Geol. Palaeont. SE Asia*, **19**, 1–27.
- KOROLEVA, M. N. 1959. New species of trilobites from the Middle and Upper Ordovician of northern Kazakhstan. *Dokl. Akad. Nauk SSSR* **124**, 1313–1316. [In Russian.]
- 1964. New Middle Ordovician trilobites *Shumardia* from northern Kazakhstan. *Paleont. Zh.* 1964 (1), 71–75. [In Russian.]
- LAI CAIGEN, WANG XIAOFENG, YI YONGEN, AN TAIXIANG, ZHANG WENTANG, QIU HONGRONG, CHEN TINGEN, FU KUN, LIN BAOYU, LIU DIYONG, and YANG JINGZHI. 1982. The Ordovician System of China. Stratigraphy of China. No. 5. 297 pp. Geol. Publishing House, Beijing. [In Chinese.]
- LAKE, P. 1907. A monograph of the British Cambrian trilobites. 2. *Palaeontogr. Soc. [Monogr.]*, 29–48.
- LANE, P. D. and OWENS, R. M. 1982. Silurian trilobites from Kap Schuchert, Washington Land, western North Greenland. *Rapp. Grouland geol. Unders.* **108**, 41–69.
- and THOMAS, A. T. 1983. A review of the trilobite Suborder Scutelluina, 141–160. In BRIGGS, D. E. G. and LANE, P. D. (eds.) Trilobites and other early arthropods. *Spec. Pap. Palaeont.* **30**, 276 pp.
- LEGG, D. P. 1976. Ordovician trilobites and graptolites from the Canning Basin, Western Australia. *Geologica et Palaeontologica* **10**, 1–58.
- LI YAOXI, SONG LISHENG, ZHOU ZHIQIANG and YANG JINGYAO 1975. *Stratigraphical Gazetteer of Lower Palaeozoic, western Dabashan*. 372 pp. Geological Publishing House, Beijing. [In Chinese.]
- LINNARSSON, J. G. O. 1869. Om Vestergötlands Cambriska och Siluriska Aflagringar. *K. Svenska Vetensk.-Akad. Handl.* **8**(2), 1–89.
- LU YANHAO. 1959. *Subdivision and correlation of the Ordovician rocks of South China*. Proceedings of Special Summaries of Geological Fundamental data of China **2**, 1–113. Geological Press, Beijing. [In Chinese with English summary.]
- 1962. Middle Ordovician index trilobites. 52–53. In WANG YU (editor): *Handbook of the Index Fossils of the Yangtze region*. Science Press, Beijing. [In Chinese.]
- 1975. Ordovician trilobite faunas of central and southwestern China. *Palaeont. sin.* **11**, 1–484.
- and CHANG WENTANG. 1974. Ordovician trilobites. 124–136. In *A handbook of Stratigraphy and Palaeontology in southwest China*. Science Press, Beijing. [In Chinese.]
- CHU CHAOLING, CHIEN YIYUAN and HSIANG LEEWEN. 1965. *Trilobites of China*. 766 pp. Science Press, Beijing [In Chinese.]
- ZHOU ZHIYI, CHEN JUNYUAN, YU WEN, CHEN XU and XU HANKUI. 1976. Ordovician biostratigraphy and palaeogeography of China. *Mem. Nanjing Inst. Geol. and Palaeont.* **7**, 1–83 [In Chinese.]
- and ZHOU ZHIYI. 1979. Systematic position and phylogeny of *Hammatoecnemis* (Trilobita). *Acta Palaeont. sin.* **18**, 415–434. [In Chinese with English summary.]
- 1981. Early Upper Ordovician trilobites from the Nanjing Hills. *Bull. Nanjing Inst. Geol. Palaeont., Acad. sin.* **3**, 1–27. [In Chinese with English abstract.]
- MAREK, L. 1952. Contribution to the stratigraphy and fauna of the uppermost part of the Králův Dvůr Shales (Ashgillian). *Sb. Ústřed. Úst. Geol. Paleont.* **19**, 429–455.
- M'COY, F. 1846. *A synopsis of the Silurian fossils of Ireland*. 72 pp. McGlashan and Gill, Dublin.
- MIKULIC, D. G. 1980. Trilobites in Paleozoic carbonate buildups. *Lethaia*, **14**, 45–56.
- MOBERG, J. C. and SEGERBERG, C. O. 1906. Bidrag till kannedomen om *Ceratopyge*-regionen med Sarskild hansyn till dess utrecking i Fogelsångstrakten. *Lunds Univ. Årsskr.* NF **2** (7), 1–113.
- MOORE, R. C. (ed.) 1959. *Treatise on Invertebrate Paleontology, Pt. O, Arthropoda I*. xix + 560 pp. The Geological Society of America and the University of Kansas Press, Lawrence, Kansas.
- NIKOLAISEN, F. 1963. The Middle Ordovician of the Oslo region, Norway. 14. The trilobite family Telephiniidae. *Norsk geol. Tidsskr.* **43**, 345–399.
- NOVÁK, O. 1883. Zur Kenntnis der böhmischen Trilobiten. *Beitr. Paläont. Geol. öst.-Ung.* **3**, 23–63.
- 1885. Studien an Hypostomen böhmischen Trilobiten. III. *Sbír. K. böhm. Ges. Wiss. Math.-nat. Kl.*, Jg 1884, 581–587.
- ÕPIK, A. 1937. Trilobiten aus Estland. *Acta Comment. Univ. tartu.* (A). **32** (3), 1–163.
- 1967. The Mindyallan Fauna of north-western Queensland. *Bull. Bur. Miner. Resour. Geol. Geophys. Aust.* **74**, 1–404.
- OSMÓLSKA, H. 1957. Trilobites from the Couvinian of Wydryszow (Holy Cross Mountains, Poland). *Acta palaeont. pol.* **2**, 53–77.
- OWEN, A. and BRUTON, D. L. 1980. Late Caradoc-early Ashgill trilobites of the central Oslo region, Norway. *Paleont. Contr. Univ. Oslo* **245**, 63 pp.
- OWENS, R. M. 1973. Ordovician Proetidae (Trilobita) from Scandinavia. *Norsk geol. Tidsskr.* **53**, 117–181.

- OWENS, R. M. 1979. The trilobite genera *Panarchaeogonus* Öpik, *Isbergia* Warburg and *Cyamops* gen. nov. from the Ordovician of Balto-Scandia and the British Isles. *Norsk geol. Tidsskr.* **58**, 199–219.
- 1981. The Ordovician proetacean trilobite *Rorringtonia*. *Geol. Mag.* **118**, 89–94.
- PEK, I. 1977. Agnostid trilobites of the central Bohemian Ordovician. *Sb. geol. Véd. paleont.* **19**, 7–44.
- PORTLOCK, J. E. 1843. *Report on the geology of the county of Londonderry, and of parts of Tyrone and Fermanagh.* xxi + 784 pp. Dublin (Milliken, Hodges and Smith) and London (Longman, Brown, Green, and Longmans).
- PRICE, D. 1974. Trilobites from the Sholeshook Limestone (Ashgill) of South Wales. *Palaentology*, **17**, 841–868.
- QIU HONGAN, LU YANHAO, ZHU ZHAOLING, BI DECHANG, LIN TIANRUI, ZHOU ZHIYI, ZHANG QUANZHONG, QIAN YIYUAN, JU TIANYIN, HAN NAIREN, and WEI XIUZHE, 1983. Trilobita. In *Palaentological Atlas of east China*. I. 28–254. Geological Publishing House, Beijing. [In Chinese.]
- RAYMOND, P. E. 1925. Some trilobites of the lower Middle Ordovician of eastern North America. *Bull. Mus. Comp. Zool. Harv.* **67**, 1–180.
- REED, F. R. C. 1896. The fauna of the Keisley Limestone. Part I. *Q. Jl. geol. Soc. Lond.* **52**, 407–437.
- 1912. Ordovician and Silurian fossils from the central Himalayas. *Mem. geol. Surv. India Palaent. indica* (15) **7** (2), 1–168.
- 1915. Supplementary memoir on new Ordovician and Silurian fossils from the Northern Shan States. *Ibid.*, ns **6** (1) 1–123.
- 1917. Ordovician and Silurian fossils from Yun-nan. *Ibid.*, **6** (3), 1–84.
- REPINA, L. N., PETRUNINA, Z. E. and HAJRULLINA, T. I. 1975. Trilobita. 100–351. In REPINA, L. N., YASKOVICH, B. V., AKSARINA, N. A., PETRUNINA, Z. E., PONIKLENKO, I. A., RUBANOV, D. A., BOLGOVA, G. V., GOLIKOV, A. N., HAJRULLINA, T. I. and POSOKHOVA, M. M. Stratigraphy and fauna of the Lower Palaeozoic of the southern submontane belt of Turkestan and the Alai ridges (southern Tien-Shan). *Trudy Inst. Geol. Geophys. Sib. Otd.* **278**, 352 pp. [In Russian.]
- ROSS, R. J. 1951. Stratigraphy of the Garden City Formation in northeastern Utah, and its trilobite faunas. *Bull. Peabody Mus. nat. Hist.* **6**, vi + 161 pp.
- 1967. Some Middle Ordovician brachiopods and trilobites from the Basin Ranges, western United States. *Prof. Pap. U.S. geol. Surv.* **523-D**, D1–D43.
- 1970. Ordovician brachiopods, trilobites and stratigraphy in eastern and central Nevada. *Prof. Pap. U.S. geol. Surv.* **639**, 1–103.
- 1972. Fossils from the Ordovician bioherm at Meiklejohn Peak, Nevada. *Ibid.*, **685**, 1–47.
- and INGHAM, J. K. 1970. Distribution of the Toquima-Table Head (Middle Ordovician Whiterock) Faunal Realm in the northern hemisphere. *Bull. Geol. Soc. Amer.* **81**, 393–408.
- SALTER, J. W. 1848. In PHILLIPS, J. and SALTER, J. W. 'Palaeontological Appendix to Professor John Phillips' memoir on the Malvern Hills, compared with the Palaeozoic Districts of Abberley, &c.' *Mem. geol. Surv. Gr. Br.* **2**, 331–386.
- 1853. Figures and descriptions illustrative of British organic remains. *Mem. geol. Surv. U.K., Decade 7*, 78 pp.
- 1864. A monograph of the British trilobites from the Cambrian, Silurian and Devonian formations. 1. *Palaentogr. Soc. [Monogr.]* 1–80.
- SARS, M. 1835. Ueber einige neue oder unvollständig bekannte Trilobiten. *Isis, Jena*, Jahrg. 1835, 4.
- SCHRANK, E. 1972. *Nileus*-Arten (Trilobita) aus Geschieben des Tremadoc bis tieferen Caradoc. *Ber. dt. Ges. geol. Wiss., A, Geol. Paläont.* **17**, 351–375.
- SHAW, F. C. 1968. Early Middle Ordovician Chazy trilobites of New York. *Mem. N.Y. St. Mus. Sci. Service*, **17**, 1–163.
- and ORMISTON, A. R. 1964. The eye socle of trilobites. *J. Paleont.* **38**, 1001–1002.
- SHENG, S. F. 1934. Lower Ordovician trilobite faunas of Chekiang. *Palaent. sin.* (B) **3** (1), 1–19.
- 1964. Upper Ordovician trilobite faunas of Szechuan-Kweichow with special discussion on the classification and boundaries of the Upper Ordovician. *Acta palaent. sin.* **12**, 553–563. [In Chinese with English summary.]
- 1974. Ordovician trilobites from western Yunnan and its stratigraphical significance. In *Subdivision and correlation of the Ordovician System in China*. T-153 Geological Publishing House, Beijing. 1–153. [In Chinese.]
- SHERBORN, C. D. 1931. *Index Animalium 1801–1850*. Part 26, Index T–Trichoscelia. 6359–6582. British Museum, London.

- SKJESETH, S. 1955. The Middle Ordovician of the Oslo region, Norway. 5. The trilobite family Styginidae. *Norsk geol. Tidsskr.* **35**, 9–28.
- TEMPLE, J. T. 1969. Lower Llandovery (Silurian) trilobites from Keisley, Westmorland. *Bull. Br. Mus. nat. Hist. (Geol.)*, **18**, 197–230.
- THOMAS, A. T. and OWENS, R. M. 1978. A review of the trilobite family Aulacopleuridae. *Palaeontology*, **21**, 65–81.
- TJERNVIK, T. E. 1956. On the early Ordovician of Sweden. Stratigraphy and fauna. *Bull. geol. Inst. Univ. Uppsala*, **36**, 107–284.
- TRIPP, R. P. 1965. Trilobites from the Albany Division (Ordovician) of the Girvan district, Ayrshire. *Palaeontology* **8**, 577–603.
- 1976. Trilobites from the basal *superstes* mudstones (Ordovician) at Aldons Quarry, near Girvan, Ayrshire. *Trans. R. Soc. Edinb.* **69**, 369–423.
- TROMELIN, G. DE and LEBESCONTE, P. 1876. Essai d'un catalogue raisonné des fossiles siluriens des départements de Maine-et-Loire, de la Loire-Inférieure et du Morbihan, avec des observations sur les terrains paléozoïques de l'Ouest de la France. *C. r. Ass. fr. Avanc. Sci., 4^{ème} session, Nantes (1875)*, 606–661.
- ULRICH, E. O. 1930. Ordovician trilobites of the family Telephidae and concerned stratigraphic correlations. *Proc. U.S. natl. Mus.* **76** (21), 1–101.
- VOGDÉS, A. W. 1890. A bibliography of Palaeozoic Crustacea from 1698 to 1889, including a list of North American species and a systematic arrangement of genera. *Bull. U.S. geol. Surv.* **63**, 1–177.
- WAHLENBERG, G. 1818. Petrifacta Telluris Svecanae. *Nova Acta R. Soc. Scient. upsal.* **8**, 1–116, 293–297.
- WARBURG, E. 1925. The trilobites of the Leptaena Limestone in Dalarne. *Bull. geol. Inst. Univ. Uppsala*, **17**, 1–446.
- 1939. The Swedish Ordovician and Lower Silurian Lichidae. *K. svenska VetenskAkad. Handl.* **17** (4), 1–162.
- WEBER, V. N. 1932. Trilobites of Turkestan. *Izd. Vses. Geol.-Razv. Ob'ed. NKTP.* iv + 157 pp. [In Russian with English summary.]
- 1948. Trilobites of the Silurian beds. No. 1. Lower Silurian trilobites. *Mon. Palaeontol. U.S.S.R.* **69** (1), 1–110. (In Russian.)
- WHITTARD, W. F. 1952. Cyclopygid trilobites from Girvan and a note on *Bohemilla*. *Bull. Br. Mus. nat. Hist. (Geol.)*, **1**, 305–324.
- 1961. The Ordovician trilobites of the Shelve inlier, west Shropshire. 6. *Palaeontogr. Soc. [Monogr.]* 197–228.
- 1966. *Ibid.* **8**, 265–306.
- WHITTINGTON, H. B. 1950. Sixteen Ordovician genotype trilobites. *J. Paleont.* **24**, 531–565.
- 1954. Ordovician trilobites from Silliman's Fossil Mount. In MILLER, A. K., YOUNGQUIST, W. and COLLINSON, C. Ordovician cephalopod fauna of Baffin Island. *Mem. geol. Soc. Amer.* **62**, 119–149.
- 1956. The trilobite family Isocolidae. *J. Paleont.* **30**, 1193–1198.
- 1963. Middle Ordovician trilobites from Lower Head, western Newfoundland. *Bull. Mus. comp. Zool. Harv.* **129**, 1–118.
- 1965. Trilobites of the Ordovician Table Head Formation, western Newfoundland. *Ibid.*, **132**, 275–441.
- 1968. A monograph of the Ordovician trilobites of the Bala area, Merioneth. 4. *Palaeontogr. Soc. [Monogr.]* 93–138.
- WILLIAMS, A., STRACHAN, I., BASSETT, D. A., DEAN, W. T., INGHAM, J. K., WRIGHT, A. D. and WHITTINGTON, H. B. 1972. A correlation of Ordovician rocks in the British Isles. *Geol. Soc. Lond. Spec. Rept* **3**, 1–74.
- XIA SHUFANG. 1978. Ordovician trilobites. 157–185. In *Sinian to Permian stratigraphy and paleontology of East Yangtze Gorge area*. Geological Publishing House, Beijing. [In Chinese.]
- YI YONGEN. 1957. The Caradocian trilobite fauna from the Yangtze Gorges. *Acta Palaeont. sin.* **5** (4), 527–560. [In Chinese with English summary.]
- YIN GONGZHENG and LEE SHANZI. 1978. Trilobita. 385–595 in *Atlas of Palaeontology of southwest China, Guizhou Province*. Geological Publishing House, Beijing. [In Chinese.]
- ZENG QINGLUAN, NI SHIZHAO, XU GUANGHONG, ZHOU TIANMEI, WANG XIAOFENG, LI ZHIHONG, LAI CAIGEN and XIANG LIWEN. 1983. Subdivision and correlation on the Ordovician in the eastern Yangtze Gorges. *Bull. Yichang Inst. Geol. Mineral Resources Chinese Acad. geol. Sci.* **10**, 1–56.
- ZHANG TAIRONG. 1981. Trilobita. 134–213. In *Palaeontological Atlas of northwest China*. Xinjiang (1). Geological Publishing House, Beijing. [In Chinese.]
- ZHOU TIANMEI, LIU YIREN, MENG XIANSONG and SUN ZHENHUA. 1977. Trilobita. In *Atlas of Palaeontology of central and south China*. Geological Publishing House, Beijing. 140–266. [In Chinese.]

- ZHOU ZHIQIANG, LEE JINGSEN and QU XINGGUO. 1982. Trilobites. 215-460. In *Palaeontological Atlas of northwest China: Shaanxi, Gansu and Ningxia Volume, Part 1, Pre-Cambrian to Early Palaeozoic*. Geological Publishing House, Beijing. [In Chinese.]
- ZHOU ZHIYI, YIN GONGZHENG and TRIPP, R. P. 1984. Trilobites from the Ordovician Shihtzupu Formation, Zunyi, Guizhou Province, China. *Trans. R. Soc. Edinb.* **75**, 13-36.

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